

Senate Rural and Regional Affairs and Transport References Committee

Written Questions on Notice from Public Hearings on Wednesday, 3 July 2013 and Thursday, 4 July 2013

Inquiry into the review of the citrus industry in Australia

Question Number	Page No's.	Witness	Question asked by	Answered
1	-	Anti-dumping Commission	Senator Ruston	Unanswered as at 16/12/2013
1	-	Mr Battistel	Senator Ruston	16/07/13
2	-	Mr Battistel	Senator Ruston	16/07/13
1	-	Citrus Australia	Senator Ruston	23/07/13
2	-	Citrus Australia	Senator Ruston	23/07/13
3	-	Citrus Australia	Senator Ruston	23/07/13
4	-	Citrus Australia	Senator Ruston	23/07/13
5	-	Citrus Australia	Senator Ruston	23/07/13
6	-	Citrus Australia	Senator Ruston	23/07/13
7	-	Citrus Australia	Senator Ruston	23/07/13
8	-	Citrus Australia	Senator Ruston	23/07/13
9	-	Citrus Australia	Senator Ruston	23/07/13
10	-	Citrus Australia	Senator Ruston	23/07/13
11	-	Citrus Australia	Senator Ruston	23/07/13
12	-	Citrus Australia	Senator Ruston	23/07/13

13	-	Citrus Australia	Senator Ruston	23/07/13
14	-	Citrus Australia	Senator Ruston	23/07/13
15	-	Citrus Australia	Senator Ruston	23/07/13
16	-	Citrus Australia	Senator Ruston	23/07/13
17	-	Citrus Australia	Senator Ruston	23/07/13
18	-	Citrus Australia	Senator Ruston	23/07/13
19	-	Citrus Australia	Senator Ruston	23/07/13
20	-	Citrus Australia	Senator Ruston	23/07/13
21	-	Citrus Australia	Senator Ruston	23/07/13
22	-	Citrus Australia	Senator Ruston	23/07/13
1	-	DAFF	Senator Ruston	17/07/13
2	-	DAFF	Senator Ruston	17/07/13
3	-	DAFF	Senator Ruston	17/07/13
4	-	DAFF	Senator Ruston	17/07/13
5	-	DAFF	Senator Ruston	17/07/13
6	-	DAFF	Senator Ruston	17/07/13
7	-	DAFF	Senator Ruston	17/07/13
8	-	DAFF	Senator Ruston	17/07/13
9	-	DAFF	Senator Ruston	17/07/13
10	-	DAFF	Senator Ruston	17/07/13
1	-	FSANZ	Senator Ruston	15/07/13
1	-	GDCG	Senator Ruston	16/07/13
1	-	HAL & IAC	Senator Ruston	23/07/13
2	-	HAL & IAC	Senator Ruston	23/07/13
3	-	HAL & IAC	Senator Ruston	23/07/13

4	-	HAL & IAC	Senator Ruston	23/07/13
5	-	HAL & IAC	Senator Ruston	23/07/13
6	-	HAL & IAC	Senator Ruston	Unanswered as at 16/12/2013
7	-	HAL & IAC	Senator Ruston	Unanswered as at 16/12/2013
8	-	HAL & IAC	Senator Ruston	23/07/13
9	-	HAL & IAC	Senator Ruston	23/07/13
10	-	HAL & IAC	Senator Ruston	23/07/13
11	-	HAL & IAC	Senator Ruston	23/07/13
12	-	HAL & IAC	Senator Ruston	23/07/13
13	-	HAL & IAC	Senator Ruston	23/07/13
14	-	HAL & IAC	Senator Ruston	23/07/13
1	-	MFC	Senator Ruston	Unanswered as at 16/12/2013
1	-	RBC	Senator Ruston	16/07/13
2	-	RBC	Senator Ruston	16/07/13

**SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
REFERENCES COMMITTEE**

Inquiry into the review of the citrus industry in Australia

Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013 and Thursday, 4 July 2013

Anti-dumping Commission

Written Questions on Notice - Senator Ruston

Question 1	Imported frozen concentrated orange juice	Can a representative body of an industry, particularly a recognised Peak Industry Body (PIB), bring on an anti-dumping application? Specifically, can Citrus Australia Ltd, on behalf of citrus growers and other citrus supply chain stakeholders, make an anti-dumping application with regard to the importation of frozen concentrated orange juice from Brazil if it believes the product is being dumped in the Australian market causing injury to its members?

**SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
REFERENCES COMMITTEE**

Inquiry into the review of the citrus industry in Australia

Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013 and Thursday, 4 July 2013

Mr Frank Battistel

Written Questions on Notice - Senator Ruston

Question 1	Citrus Australia Ltd	In your evidence (p18, Griffith 3 July 2013) you referred to a letter of refusal from Citrus Australia Ltd in relation to an offer by Riverina Citrus to provide funding for promotions: "They refused that—I could have brought the letter of refusal—basically stating that they did not want to be directed or told the direction in which they, the Citrus Australia board, should be heading, by growers." Can you please provide a copy of this letter?
Question 2	Minimum juice content	In evidence (p17, Griffith 3 July 2013) you said it would be possible get some more detail on notice of your proposal about minimum Australian juice content. Can you please provide this detail as indicated?

**SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
REFERENCES COMMITTEE**

Inquiry into the review of the citrus industry in Australia

Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013 and Thursday, 4 July 2013

Mr Frank Battistel

Written Questions on Notice - Senator Ruston

Question 1	Citrus Australia Ltd	In your evidence (p18, Griffith 3 July 2013) you referred to a letter of refusal from Citrus Australia Ltd in relation to an offer by Riverina Citrus to provide funding for promotions: "They refused that—I could have brought the letter of refusal—basically stating that they did not want to be directed or told the direction in which they, the Citrus Australia board, should be heading, by growers." Can you please provide a copy of this letter?
Question 2	Minimum juice content	In evidence (p17, Griffith 3 July 2013) you said it would be possible get some more detail on notice of your proposal about minimum Australian juice content. Can you please provide this detail as indicated?

Answers:

Question 1

The letter that was sent to us by CAL back in 2008/9 stating that they could not except money offered by Riverina Citrus (RC) to carry out certain function which was part of their functions anyway. It was double standards that CAL did except monies from QLD mandarin growers to be spent on QLD growers only given that we did not even ask for our monies to be spent on RC specific functions. The letters have been provided in an attachment.

Question 2

I refer to my letter submitted to the inquire on local minimum content (LMC) I would like to add that in the early 90s we did have a LMC of 25% which would have much of the detail on how it was applied and how the tax was collected. My LMC would only apply to Juice that uses 100% imported concentrate so as to utilise the current dumped Navel blemish and out of size fruit. Processor will argue that they cannot use Navel orange concentrate because it bitters but this has been used in the past and they currently use up to 25% Navel juice in fresh juice due to its nil value for off run Navel oranges so mixing 25% Navel concentrate to 75% imported Valencia concentrate is achievable.



12 December 2008

CONFIDENTIAL

Kevin Cock
President
Citrus Australia Limited
PO Box 5091
Mildura Vic 3501

RE: Regional priorities for citrus growers of the Riverina

Dear Kevin and Citrus Australia Committee members,

Representatives of Griffith & District Citrus Growers Inc., Leeton Citrus Growers Inc. and Riverina Citrus met on the 10th of December 2008 to discuss the current and ongoing future operations of the regional Riverina citrus organisations with Citrus Australia Ltd.

From this meeting the following regional citrus issues were listed (in no particular order) as priorities from the Riverina for the Citrus Australia Ltd Board to consider.

- Improved returns for citrus growers.
 - CAL to implement collective bargaining with juice processors in order to achieve a minimum price that reflects cost of production and a return on investment
- Coordinated marketing into selected markets. (Similar to the current US citrus export conditions.)
- Market access
 - Improved access conditions to address MIA conditions and priorities to current export and domestic markets. (BA, AQIS, PHA, Interstate trade)
 - Fruit fly related market access issues.
- National promotion

Notes:

- Improving processing and export markets will have a positive flow onto the domestic market and will allow for targeted national promotion rather than generic promotional activities.
- Achieving results in these areas will greatly increase grower support for CAL.

Within the operational funding of Riverina Citrus, an indicative amount of \$200,000 plus in-kind (inclusive of the historic service agreement with ACG Inc.), could be allocated to outsource these priority activities. Key performance indicators would need to be set to determine payment levels for timely services provided.

Riverina Citrus is required under legislation to have its budget approved annually by a meeting of its constituents before the end of April. Development of the Riverina Citrus budget will begin in January 2009 with input from Griffith & Leeton Citrus grower organisations.

A response, by mid February 2009, to this letter would be appreciated from Citrus Australia on the organisations strategies, actions and ability to obtain results on the major priorities listed to assist in allocating funds within the Riverina Citrus 2009-2010 Budget.

Representatives of the three regional groups are prepared to travel to meet with the CAL Board to discuss further or clarify these priorities as required.

The citrus committees of the Riverina also propose that the CAL Board consider holding a regular Board meeting in the Riverina citrus growing region with an open session for growers to provide feedback on operations and discuss issues of priority.

Current grower feedback in the region on the structural changes highlights they are waiting to see results from CAL before any major changes to the current regional structure, while being prepared to work towards the longer term goal.

We look forward to your response and continued positive working relationship between our organisations.

Yours Sincerely

Frank Battistel
Chairman Riverina Citrus

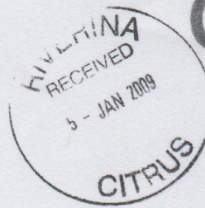
With approval
Joe Valenzisi
President
Leeton Citrus Growers Inc.

Bart Brighenti
President
Griffith & District Citrus Growers Inc.

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22 December 2008

Frank Battistel
Chairman
Riverina Citrus
PO Box 1432
GRIFFITH NSW 2680

CONFIDENTIAL

Dear Frank

Thank-you for your letter received 15 December 2008 regarding regional priorities for citrus growers of the Riverina.

I am pleased to see such a proactive and collaborative response to the change to Citrus Australia and as a follow up to our grower meeting held in Leeton on 27 November 2008.

The priorities from the Riverina, which include improved return to growers; market access; coordinated marketing and national promotion, have all been identified as part of Citrus Australia's national strategic plan. We believe that Citrus Australia can more effectively address the priorities for the Riverina by having effective grower membership with voting rights from the region. We also believe a strong working relationship between Citrus Australia and regional organisations needs to continue without the need for formal service agreements or membership.

The Citrus Australia Board spent considerable time at its recent December meeting discussing its potential affiliate members and, in order to reduce unnecessary administration of grower funds between organisations, has decided not to accept citrus organisations as formal affiliate members.

Citrus Australia would like the focus on individual growers joining as Grower Members with full voting rights, but is still prepared to work with the regional organisations to assist with advice on regional issues and transitional arrangements in achieving direct membership.

We have also agreed to set up a Riverina grower member project group with the aim of developing or assisting with a regional-specific transitional plan in 2009.

We look forward to a continued positive working relationship between Citrus Australia, Leeton Citrus Growers, Griffith & District Citrus Growers and Riverina Citrus.



On this note I am in Griffith on 14 -15 January 2009 travelling with DNE for the US grower forum and would be happy to meet with representatives of Riverina Citrus, Leeton Citrus Growers and Griffith & District Citrus Growers to discuss this further.

Trusting we will meet the needs of all parties concerned to benefit Citrus Australia Limited members as we strive to ultimately improve returns to growers.

Yours sincerely,

A handwritten signature in dark ink, appearing to read "K. Cock".

Kevin Cock
Chair

CC: Joe Valenzisi, President/Leeton Citrus Growers Inc.
Bart Brighenti, President/Griffith & District Citrus Growers Inc

[REDACTED]

**SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
REFERENCES COMMITTEE**

Inquiry into the review of the citrus industry in Australia

Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013 and Thursday, 4 July 2013

Citrus Australia Ltd

Written Questions on Notice - Senator Ruston

Question 1	Establishment registration charge for horticultural exporters	Can Citrus Australia Ltd advise if it would support a sliding scale payment structure, such as one based on volume or value of exports, for the establishment registration charge on citrus exporters?
Question 2	Imported frozen concentrated orange juice	Can Citrus Australia Ltd advise if it has ever applied, or investigated the possibility of applying, to the Anti-dumping Commission to have anti-dumping measures taken against a country they believed had been injuring the Australian citrus industry? Can Citrus Australia Ltd further advise if it would consider taking such an action if it believed a country was injuring the Australian citrus industry?
Question 3	Carbendazim	Can Citrus Australia Ltd advise of its position on carbendazim in imported Brazilian frozen concentrated orange juice: • did Citrus Australia Ltd have a position on the removal and re-instatement of the maximum residue level (MRL); • did Citrus Australia Ltd make any approaches to the Australian Government at the time; and • would Citrus Australia Ltd support action to remove the MRL now?
Question 4	Industry statistics	Can Citrus Australia Ltd provide industry statistics including: • number of growers (levy payers) in the Australian citrus industry; • number of hectares planted to citrus in Australia, broken down by varieties (navels, Valencia, juicing fruit, other); and • citrus production in Australia, broken down by varieties (navels, Valencia, juicing fruit, other). •
Question 5	Export Efficiency Powers	Can Citrus Australia Ltd advise of its position on the removal of Export Efficiency Powers?

Question 6	Pre-clearance	Can Citrus Australia Ltd advise of its position on pre-clearance of shipments to protocol markets?
Question 7	Marketing levy	Can Citrus Australia Ltd advise why the marketing levy is only payable on oranges?
Question 8	Marketing levy	Can Citrus Australia Ltd advise if it has sought to have the levy extended to other citrus?
Question 9	Marketing levy	Can Citrus Australia Ltd advise if it has approached the Australian Government to request that the marketing levy be applied to imported fruit?
Question 10	Membership	Can Citrus Australia Ltd advise how many of its grower members pay membership fees in excess of \$5000 per year?
Question 11	Membership	In the report <i>A Business Case to review two proposed restructure options for the Australian Citrus Industry</i> (Deloitte, May 2008) provided as an appendix in Citrus Australia Ltd's submission, the table on page 59 <i>Assumed Single Structure Option</i> states that net membership fee income will be \$2.42 million in year one; in the <i>Information Memorandum Citrus Australia Ltd</i> provided as an appendix in Citrus Australia Ltd's submission, the table on page 21 states membership fee income will be \$92,706 in year one. Can Citrus Australia Ltd advise of the rationale for the shift from \$2.4 million to \$92,706 in membership fee income projection?
Question 12	Membership	Can Citrus Australia Ltd provide a copy of the business plan which identified how Citrus Australia Ltd was intending to fund all the functions and activities that were previously funded by State and regional bodies, given the reduction in membership fee income of more than 95% between the report <i>A Business Case to review two proposed restructure options for the Australian Citrus Industry</i> (Deloitte, May 2008) provided as an appendix in Citrus Australia Ltd's submission and the <i>Information Memorandum Citrus Australia Ltd</i> provided as an appendix in Citrus Australia Ltd's submission?
Question 13	Membership	Can Citrus Australia Ltd advise if it has ever offered to waive or discount membership fees for any members?
Question 14	Grant income	Provide details of the total amount of funds received by Citrus Australia Ltd from Horticulture Australia Ltd for the years 2008-09, 2009-10, 2010-11, 2011-12 and 2012-13, broken down by the following categories: • research and development; • marketing; • project management; • communications; and • other.
Question 15	Grant income	In evidence (p72, Mildura 4 July 2013) Citrus Australia Ltd stated: "The \$170,000 that I think you have been told is our membership fee income is supplemented by up to \$600,000 to \$700,000 of non-grant income. So it is not the only thing that we use to run our core part of our business." Can you advise of the sources of this funding and specifically advise whether any of this additional \$600,000 to \$700,000 is received from Horticulture Australia Ltd?

Question 16	Grant income	In evidence (p72, Mildura 4 July 2013) Citrus Australia Ltd stated that “We mentioned it in the opening statement. For example, we run the 'Give me a mandy Mum' promotional program, and the contributors pay about \$300,000 to \$350,000 to help run that program. That is just one project. That is not a grant or a HAL R&D project. Sponsorship for conferences and advertising is about \$150,000. We have subscriptions—”. Can Citrus Australia Ltd advise if all of the \$300,000 to \$350,000 mentioned above are spent on the ‘Give me a mandy Mum’ promotion? Can Citrus Australia Ltd further advise if all of the \$150,000 mentioned above is used for conferences and advertising?
Question 17	Board	Can Citrus Australia Ltd provide a list of the directors and employees of Citrus Australia Ltd which indicates whether any of these people are also members of any of the following: • Citrus IAC; • selection panel for the appointment of the Citrus IAC; • IAC Technical Reference Committee; and • selection panel for the appointment of the IAC Technical Reference Committee.
Question 18	Board	In the report <i>A Business Case to review two proposed restructure options for the Australian Citrus Industry</i> (Deloitte, May 2008) provided as an appendix in Citrus Australia Ltd’s submission, the table on page 59 <i>Assumed Single Structure Option</i> shows the funds allocated for Board fees and expenses was between \$443,700 (year one) and \$480,275 (year five); in the <i>Information Memorandum Citrus Australia Ltd</i> provided as an appendix in Citrus Australia Ltd’s submission, the table on page 21 states that these expenses are \$166,000 in year one. Can you advise of the actual amount of these expenses in the last financial year?
Question 19	Board	Can Citrus Australia Ltd provide a list of the people who sit on the selection panel that recommends the directors of Citrus Australia Ltd.
Question 20	Juice prices	In evidence (p68, Mildura 4 July 2013) Ms Chapman (chair, Citrus Australia Ltd) stated: “It was only last February that processors were out there paying \$700 to \$750 per tonne for juicing fruit. Those prices are not even heard of. That was the same year I was selling my navels for \$200 to \$250 a tonne.” Can Citrus Australia Ltd advise of the names of any processors who actually paid growers \$700 to \$750 per tonne for juicing fruit last February, to whom it was offered and for what period of time the offer was valid? Can Citrus Australia Ltd further advise if there were any particular fruit quality requirements growers had to meet in order to obtain \$700-750 per tonne?
Question 21	Riverina Citrus	In evidence (p18, Griffith 3 July 2013) it was stated that Citrus Australia Ltd had refused funds offered by Riverina Citrus for promotional purposes. If this is the case, can Citrus Australia Ltd advise why it did not accept these funds, and advise the difference between these funds and those provided by Queensland mandarin growers that were accepted by Citrus Australia Ltd?

Question 22	Biosecurity	In evidence (p65, Mildura 4 July 2013) Committee Chair Senator Heffernan asked Ms Damiani (chief executive officer Citrus Australia Ltd): <i>CHAIR: What is the estimated damage if there is an incursion of HBL [Huanglongbing], if you have a plan? It is about \$8 million for the cattle industry for foot and mouth. What is yours?</i> <i>Ms Damiani: I think it depends on what scenario you use. Where is it found? When is it found?</i> <i>CHAIR: If it comes in on a cyclone, it might go to Moree or wherever—I don't know—there would be a contingency about borders and a whole lot of rigmarole around that. It really would not matter much. Have you got a contingency plan if it comes in from wherever? I do not know where it is going to come in from. The department did not even seem to know where it was, which surprised me, and they did not seem to know whether there was a contingency plan. Have you talked to the department about this? Who organised the contingency plan?</i> <i>Ms Damiani: We work through Plant Health Australia on any contingency plans. We have been working through them. We have also utilised the expert experience from a number of entomologists and pathologists.</i> <i>CHAIR: Could you table the contingency plan.</i> <i>Ms Damiani: Yes, I would be happy to.</i> Can Citrus Australia Ltd provide a copy of the above-mentioned contingency plan they have prepared in conjunction with Plant Health Australia?

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Citrus Australia Ltd

Written Questions on Notice - Senator Ruston

Question 1	Establishment registration charge for horticultural exporters	Can Citrus Australia Ltd advise if it would support a sliding scale payment structure, such as one based on volume or value of exports, for the establishment registration charge on citrus exporters?
Response Q1		The Horticulture Exports Industry Consultative Committee (the Committee) is the principal forum for the Department of Agriculture, Fisheries and Forestry (DAFF) to consult with horticultural industries on export inspection and certification, and other relevant issues. The Committee aims to provide effective consultation, communication and partnership between DAFF and industry stakeholders involved in phytosanitary exports by ensuring stakeholders' views are given due consideration. The DAFF Horticulture Exports Program only introduces major policy or operational changes after the Committee has been consulted. Citrus Australia has only one representative on this committee of nine. Citrus Australia is (again) prepared to brief our representative to place on the Committee agenda a review of the export registration fees in order to establish a more equitable arrangement. Citrus Australia has already expressed concern to DAFF regarding the requirement for all citrus export packing sheds to be registered regardless for the need to undertake on-site inspections. There is an opportunity for export packing sheds to reduce or negate their establishment charge by having their product inspected at a freight forwarder, treatment facility or other third party. Citrus Australia will need to undertake its normal consultation (national export advisory committee, mandarin export group, other grower/packer/exporters, Citrus Australia Board etc) on options developed by DAFF and the Committee before supporting any change to establishment registration charges.

Question 2	Imported frozen concentrated orange juice	Can Citrus Australia Ltd advise if it has ever applied, or investigated the possibility of applying, to the Anti-dumping Commission to have anti-dumping measures taken against a country they believed had been injuring the Australian citrus industry? Can Citrus Australia Ltd further advise if it would consider taking such an action if it believed a country was injuring the Australian citrus industry?
Response Q2		Citrus Australia has not applied to the Anti-Dumping Commission to have anti-dumping measures applied. Citrus Australia has welcomed the establishment of a new anti-dumping commission announced in December 2012 (refer to media release below): The Anti-Dumping Commission commenced operations on Monday 1 July 2013. Citrus Australia, after its normal consultation process, would consider taking action if a country was believed to be injuring the Australian citrus industry. Anti-dumping commission to be set up <i>Alex Sampson</i> Weekly Times December 11, 2012 <i>AUSTRALIAN industry has welcomed the establishment of a new anti-dumping commission.</i> <i>Under the commission, trade inspectors would be based in Victoria in an attempt to quash the rise of cheap imports dumped on Australian markets.</i> <i>The government will provide Customs with an extra \$24.4 million a year and 55 new investigators for small and medium-sized firms to help combat global companies.</i> <i>Prime Minister Julia Gillard last week committed the government to act upon key recommendations in the Brumby anti-dumping review and establish an anti-dumping commission.</i> <i>She said the move would fight the uneven playing field for Australian manufacturers and boost protection against unfair competition from overseas.</i> <i>"It's neither fair nor efficient for Australian manufacturers or their workers to be harmed economically by products dumped into Australia," she told News Limited.</i> <i>The government said complaints against anti-dumping had tripled in the past two years.</i> <i>Dumping involves goods being exported to Australia cheaper than their ordinary value, below the domestic value of the product in the country it has come from.</i>

		<i>Australian-made products affected by dumping in recent years include steel, chemicals, aluminium goods, paper products and fresh produce.</i> <i>Manufacturing provides a quarter of Australia's business research and development expenditure, a third of its traditional trade apprenticeship completions and almost 30 per cent of its exports.</i> <i>Peak industry body AusVeg public spokesman William Churchill said the Australian vegetable industry, like those in the manufacturing sector, had borne the brunt of actions by foreign countries to "subvert the ideals of free trade".</i> <i>"Trade as a tool is helpful to everyone when we operate on a level playing field, but some foreign countries bend the rules, subsidising industries to stamp out competition," he said.</i> <i>"It should be applauded that steps are now being taken to establish an outfit capable of pursuing those who are causing injury to Australian industry."</i> <i>Citrus Australia chief executive Judith Damiani also welcomed the announcement, saying it would help protect the industry against cheap imported orange juice.</i> <i>"It will be very important in making it easier for small to medium businesses to make claims against anti-dumping," Ms Damiani said.</i> <i>The Government will introduce legislation for the anti-dumping commission next year.</i> <i>The Government will support manufacturing by strengthening the system for investigating dumping and applying remedies where dumping is injuring local producers.</i> <i>The key reforms will:</i> <i>- Establish a new Anti-Dumping Commission to investigate complaints;</i> <i>- Boost funding to Customs by \$24.4 million over four years so it can deal with cases speedily and fairly - this will almost double the number of investigators;</i> <i>- Make the anti-dumping system easier for small and medium-sized businesses; and</i> <i>- Introduce stricter remedies against overseas producers who deliberately circumvent Australia's anti-dumping rules.</i>
Question 3	Carbendazim	Can Citrus Australia Ltd advise of its position on carbendazim in imported Brazilian frozen concentrated orange juice: • did Citrus Australia Ltd have a position on the removal and re-instatement of the maximum residue level (MRL);

		• did Citrus Australia Ltd make any approaches to the Australian Government at the time; and • would Citrus Australia Ltd support action to remove the MRL now?
Response Q3		Citrus Australia, upon learning about the action being taken in the US on imported juice due to carbendazim scare, immediately called for, and welcomed, increased testing of imported juice – see media releases below: 13 January 2012 MEDIA RELEASE Citrus Australia Calls for Increased Testing of Imported Juice <i>Citrus Australia has called for the Australian Government to increase testing procedures on imported citrus juice, and consumers to look for safe, branded local products in the wake of a chemical residue scare in the U.S.</i> <i>“The fungicide, called Carbendazim, which was identified in some imported fruit juices in the U.S. was withdrawn from use in the Australian citrus industry over two years ago,” said Judith Damiani, CEO of Citrus Australia.</i> <i>The residue issue came to light when a major juice manufacturer wrote to the U.S. Food & Drug Administration (FDA) saying that it had detected 35 parts per billion of the fungicide in its own orange juice as well as competitors' juice. Although that level is far below the mandated maximum residue level of 200 parts per billion, the alarm was raised because of the health issues that the fungicide poses. Attention centred on Brazilian juice because it accounts for almost one in every six glasses of orange juice consumed in the U.S.</i> <i>On January 4 the FDA suspended all imports of foreign orange juice and began stringent testing for traces of Carbendazim.</i> <i>“In Australia over 300,000 tonnes of oranges are imported every year in the form of cheap Brazilian orange juice concentrate. We call on the Australian Quarantine & Inspection Service to immediately increase testing of all imported citrus juice for chemicals banned in Australia.</i> <i>“Australian Consumers can be confident about their fresh juice purchases if they buy from the chiller section of their local shop or supermarket, and look for juices that have the Aussie Grown logo or Product of Australia on their packaging,” said Ms. Damiani</i> <i>The Aussie Grown, supported by Australian Citrus Growers logo indicates the endorsement of Citrus Australia, the peak industry body of the citrus sector in Australia. The logo cannot be bought and is designed to help consumers make an informed choice when buying Australian juices. Citrus Australia exists purely for the benefit of Australian farmers so its endorsement is not tarnished by any motive except to provide a retail edge to companies that support locally grown produce.</i> <i>The following Australian juices proudly use the endorsement logo: Berri Australian Grown, Original Juice Black Label Orange Juice, Curlwaa Fresh Orange Juice and Nippy's Orange Juice.</i> Ends

**20 January 2012
MEDIA RELEASE**

Citrus Australia Welcomes Enhanced Testing of Imported Orange Juice

Citrus Australia has welcomed the advice from Food Standards Australia New Zealand (FSANZ) that testing for carbendazim in imported orange juice will commence. No oranges or orange juice sold in Australia will be permitted to contain the fungicide carbendazim.

Citrus Australia recently raised concerns after the US Food and Drug Agency detected trace amounts of carbendazim in orange juice imported from Brazil.

FSANZ have conducted a risk assessment based on the recent reports and have concluded that exposure to carbendazim through consuming orange juice is extremely low. In fact a 60kg adult would have to drink more than 145 litres of orange juice in a day before going over the safe level.

Australia imports most of its orange juice concentrate from Brazil where the use of the fungicide is legal. However carbendazim is banned from use in the Australian citrus industry and now all imported citrus products are also required to comply with the same standard.

“This means that carbendazim in orange juice is an unlawful chemical residue under Australian law,” said Judith Damiani, CEO of Citrus Australia. “The Australian Quarantine and Inspection Service will start sampling shipments of imported orange juice for carbendazim and will take action on non-compliance. We will monitor the results of that testing closely.

***“In the meantime we urge everyone to buy fresh Australian orange juice or Australian Valencia oranges to squeeze at home. Make sure you buy Aussie juice or Aussie Valencia oranges for your breakfast or BBQ on Australia Day!”
More information on carbendazim can be found on the FSANZ website
www.foodstandards.gov.au***

To find Australian fresh juice in your supermarket chiller aisle, look for packaging labelled Product of Australia and/or the Aussie Grown, Supported by Australian Citrus Growers logo – indicating the endorsement of Citrus Australia. The logo cannot be bought and is designed to help consumers make an informed choice when buying Australian juices. The following Australian juices proudly use the endorsement logo: Berri Australian Grown, Original Juice Black Label Orange Juice, Curlwaa Fresh Orange Juice and Nippy’s Orange Juice.

ENDS

Citrus Australia then worked with Senator Nick Xenophon – see media release below:

Thursday 16 February 2012

Revealed: Industry pressure allows banned chemical in imported juice

Independent Senator for South Australia, Nick Xenophon, has slammed Food Standards Australia and New Zealand (FSANZ) for back-flipping on its decision to ban the import of carbendazim-laced Brazilian orange juice concentrate.

In a letter to Senator Xenophon in January, Parliamentary Secretary for Health and Ageing, the Hon Catherine King MP, stated that orange juice concentrate containing any level of the fungicide would not be permitted to be imported into Australia after April 2012.

However in his appearance before Senate Estimates this evening, FSANZ Chief Executive Officer, Steve McCutcheon, effectively admitted that lobbying from juice processors was a key factor in forcing a last-minute "review" of this ban.

"Again we see the big end of town putting the squeeze on small producers," Nick said.

"The citrus industry in Australia was effectively banned from using this chemical over two years ago, yet FSANZ decide to wait for another review before banning the harmful fungicide at the import level."

Mr McCutcheon also made the admission that an Australian consumer buying orange juice labelled as 'Australian Made' could be drinking a product that consists of up to 70 or 80 per cent Brazilian concentrate.

"This clearly highlights just how pathetic our food labelling laws are," Nick said. "'Australian Made' should mean just that."

Senator Xenophon has also hit out at FSANZ for not adequately publicising this back-flip until questioned by the Committee, admitting it only published the information in a fact sheet on its website.

"The growers I speak with in the Riverland don't spend too much on the internet searching for fact sheets," Nick said.

"FSANZ may try and bury the facts, but they certainly can't bury this issue."

Ends

		<i>For more information contact Nick Xenophon on 0411 626 677 or Sally Ward on 0409 869 689</i> <i>For comment from Australian producers, contact Judith Damiani (CEO of Citrus Australia) on 0418 891 814</i> Citrus Australia also raised the concern regarding the carbendazim issue with the Australian Government Minister for Agriculture at a meeting held in Canberra on 18 September 2012. Citrus Australia is yet to receive clarification from the APVMA or FSANZ regarding the new MRL for carbendazim. Before any action is taken, we would be seeking answers to questions such as: Are Australian citrus growers now allowed to use this chemical? Was increased testing on imported orange juice carried out at the border? What was the result of the increased testing against the new MRL?
Question 4	Industry statistics	Can Citrus Australia Ltd provide industry statistics including: • number of growers (levy payers) in the Australian citrus industry; • number of hectares planted to citrus in Australia, broken down by varieties (navels, Valencia, juicing fruit, other); and • citrus production in Australia, broken down by varieties (navels, Valencia, juicing fruit, other). •
Response Q4		Yes. Attachments: 2011 national citrus plantings database; 2013 crop forecast
Question 5	Export Efficiency Powers	Can Citrus Australia Ltd advise of its position on the removal of Export Efficiency Powers?
Response Q5		See Attachment: Citrus Australia submission to review August 2012; In November 2012 the Agriculture Minister, in a letter to Citrus Australia, sought a more definitive way forward. Citrus Australia proceeded to consult the major citrus grower/exporters to the US, including Riversun, AgriExchange, Mildura Fruit Company, SimFresh and Pacific Fresh. The Citrus Australia Board then considered the industry feedback and responded to the Minister as follows:

		“That the Minister supports short-term transition arrangements for the removal of export efficiency powers by maintaining the regulated markets for China (unchanged) and USA (with amendments) for 2 seasons. The amendments for the US market involve the replacement of the single importer arrangement with DNE World Fruit Sales with a Citrus to USA committee, similar to the Citrus to China committee. This committee sets minimum exporter to packer prices for the regulated market. This is the position the majority of industry is now prepared to consider, and gives a level of assurance to protecting grower returns during the reforms.”
Question 6	Pre-clearance	Can Citrus Australia Ltd advise of its position on pre-clearance of shipments to protocol markets?
Response Q6		The Australian citrus industry is keen to explore pre-clearance program options; to mitigate the risks associated with costly on-arrival detections/rejections (estimated at \$25 000 per container or more). Citrus Australia supports any approach that would provide growers and exporters with new opportunities and reduce business risks/costs and has previously consulted widely on this issue. The pre-clearance program currently in place for Korea has proved very successful over the last three seasons, with no on-arrival issues. As a consequence, trade is building steadily into this valuable market and the pre-clearance program continues to have industry support. In the case of Thailand, a large number of rejections have occurred over the last few seasons that have been very costly; as Thailand offers no remedial treatment and goods have to be either re-exported or destroyed. A pre-clearance program would mitigate the risks associated with on-arrival rejections. At this stage, DAFF has not agreed to move to a pre-clearance program for Thailand. In the absence of a pre-clearance program for Thailand, citrus exporters are less likely export this season due to issues in previous years. It is worth noting that the USA exports over one million cartons of citrus to Australia annually under a voluntary pre-clearance arrangement and the Australian Government supports that program as well as other pre-clearance import programs.
Question 7	Marketing levy	Can Citrus Australia Ltd advise why the marketing levy is only payable on oranges?
Response Q7		Apparently this was a historical decision taken when national citrus levies were first introduced by the then peak industry body Australian Citrus Growers Federation.
Question 8	Marketing levy	Can Citrus Australia Ltd advise if it has sought to have the levy extended to other citrus?
Response Q8		Citrus Australia has not yet sought to have the marketing levy extended to other citrus, but is in active consultation to gauge support, as the eligible industry body for citrus under the <i>Primary Industries (Excise) Levies Regulations 1999</i> and <i>The Primary Industries (Customs) Charges Regulations 2000</i> .

		The previous national peak body Australian Citrus Growers Inc undertook consultation and conducted a ballot in 2003 to increase national R&D levy to \$3.00 per tonne; to increase the marketing levy on mandarins to \$5.00 per tonne and to increase the marketing levy on all other citrus to \$1.50 per tonne. Levy payers voted against all three increases.
Question 9	Marketing levy	Can Citrus Australia Ltd advise if it has approached the Australian Government to request that the marketing levy be applied to imported fruit?
Response Q9		No, Citrus Australia has not. It would be worth noting the difficulty the industry may face in having to promote both Australian and imported fruit, and the small amount that would be actually raised from imported oranges (i.e. approximately \$20,000 less DAFF Levies Revenue Service and HAL costs).
Question 10	Membership	Can Citrus Australia Ltd advise how many of its grower members pay membership fees in excess of \$5000 per year?
Response Q10		4
Question 11	Membership	In the report <i>A Business Case to review two proposed restructure options for the Australian Citrus Industry</i> (Deloitte, May 2008) provided as an appendix in Citrus Australia Ltd's submission, the table on page 59 <i>Assumed Single Structure Option</i> states that net membership fee income will be \$2.42 million in year one; in the <i>Information Memorandum Citrus Australia Ltd</i> provided as an appendix in Citrus Australia Ltd's submission, the table on page 21 states membership fee income will be \$92,706 in year one. Can Citrus Australia Ltd advise of the rationale for the shift from \$2.4 million to \$92,706 in membership fee income projection?
Response Q11		No, the <i>Business Case</i> (2008) and <i>Information Memorandum</i> (2008) were prepared prior to the establishment of Citrus Australia.
Question 12	Membership	Can Citrus Australia Ltd provide a copy of the business plan which identified how Citrus Australia Ltd was intending to fund all the functions and activities that were previously funded by State and regional bodies, given the reduction in membership fee income of more than 95% between the report <i>A Business Case to review two proposed restructure options for the Australian Citrus Industry</i> (Deloitte, May 2008) provided as an appendix in Citrus Australia Ltd's submission and the <i>Information Memorandum Citrus Australia Ltd</i> provided as an appendix in Citrus Australia Ltd's submission?
Response Q12		Citrus Australia has never intended to fund all the functions and activities that were previously funded by State and regional bodies. The principle was to simplify the complex, costly and inefficient multi-structure and ensure the top regional priorities and services were addressed through either Citrus Australia (industry/market development, advocacy) or an enhanced national levy system which leverages dollar for dollar matching R&D funds from the Australian Government.

Question 13	Membership	Can Citrus Australia Ltd advise if it has ever offered to waive or discount membership fees for any members?
Response Q13		Yes, for example a discount of 5% off the total membership fee was offered to any grower member renewing or joining before the 30 June 2013.
Question 14	Grant income	Provide details of the total amount of funds received by Citrus Australia Ltd from Horticulture Australia Ltd for the years 2008-09, 2009-10, 2010-11, 2011-12 and 2012-13, broken down by the following categories: • research and development; • marketing; • project management; • communications; and • other.
Response Q14		See attachment: Summary of HAL funded R&D projects managed by Citrus Australia 2010-2016
Question 15	Grant income	In evidence (p72, Mildura 4 July 2013) Citrus Australia Ltd stated: "The \$170,000 that I think you have been told is our membership fee income is supplemented by up to \$600,000 to \$700,000 of non-grant income. So it is not the only thing that we use to run our core part of our business." Can you advise of the sources of this funding and specifically advise whether any of this additional \$600,000 to \$700,000 is received from Horticulture Australia Ltd?
Response Q15		Citrus Australia's full financial and audited statements from 2009/10 to 2011/12 show an annual average of \$839,820 received from non-HAL income. This income is derived from membership, subscriptions/registrations, advertising, sponsorship, corporate partners, voluntary contributions, other grant income, interest, fee-for-service and other income.
Question 16	Grant income	In evidence (p72, Mildura 4 July 2013) Citrus Australia Ltd stated that "We mentioned it in the opening statement. For example, we run the 'Give me a mandy Mum' promotional program, and the contributors pay about \$300,000 to \$350,000 to help run that program. That is just one project. That is not a grant or a HAL R&D project. Sponsorship for conferences and advertising is about \$150,000. We have subscriptions—". Can Citrus Australia Ltd advise if all of the \$300,000 to \$350,000 mentioned above are spent on the 'Give me a mandy Mum' promotion? Can Citrus Australia Ltd further advise if all of the \$150,000 mentioned above is used for conferences and advertising?
Response Q16		Citrus Australia manages an annual domestic promotion program for Australian mandarins, which is funded voluntarily and predominantly from many Queensland growers and some of their wholesalers based in Brisbane and Melbourne. There have also been voluntary contributions from mandarin growers and packers in Victoria and South Australia. Citrus Australia also applied and received a grant of \$76,676 in 2010/11 from DAFF's Promoting Australian Produce program to support the promotion of Australian mandarins. In Citrus Australia's full financial and audited statements from 2009/10 to 2011/12 the annual income for this program averaged \$ 422,179 (excluding the DAFF

		grant). These funds are used to manage, execute, monitor, evaluate, communicate and report on the “Give me a Mandy Mum” promotion program, and to address other high priority mandarin-related issues. Conference sponsorship is used against conference expenses; advertising income is used against the cost of our publications. The balance is taken up by Citrus Australia.
Question 17	Board	Can Citrus Australia Ltd provide a list of the directors and employees of Citrus Australia Ltd which indicates whether any of these people are also members of any of the following: • Citrus IAC; • selection panel for the appointment of the Citrus IAC; • IAC Technical Reference Committee; and • selection panel for the appointment of the IAC Technical Reference Committee.
Response Q17		Citrus Australia Directors Tania Chapman, Greg Dhnaram, and Kevin Cock are members of the HAL Citrus IAC, three out of the ten members. Citrus Australia Chair Tania Chapman was a member of the selection panel for the appointment of the HAL Citrus IAC. Citrus Australia employee Andrew Harty is a member of the HAL Citrus IAC Technical Reference Committee. HAL appointed the Citrus IAC Technical Reference Committee.
Question 18	Board	In the report <i>A Business Case to review two proposed restructure options for the Australian Citrus Industry</i> (Deloitte, May 2008) provided as an appendix in Citrus Australia Ltd’s submission, the table on page 59 <i>Assumed Single Structure Option</i> shows the funds allocated for Board fees and expenses was between \$443,700 (year one) and \$480,275 (year five); in the <i>Information Memorandum Citrus Australia Ltd</i> provided as an appendix in Citrus Australia Ltd’s submission, the table on page 21 states that these expenses are \$166,000 in year one. Can you advise of the actual amount of these expenses in the last financial year?
Response Q18		Yes, the actual expense for the Citrus Australia Board in 2011/12 was \$199,555 and includes remuneration, superannuation, Board meeting travel, regional forum travel, meeting and sub-committee expenses including director selection committee.
Question 19	Board	Can Citrus Australia Ltd provide a list of the people who sit on the selection panel that recommends the directors of Citrus Australia Ltd.
Response Q19		Yes: Richie Roberts, Susan Chislett, Kevin Parr and Dean Morris, as grower members of Citrus Australia.
Question 20	Juice prices	In evidence (p68, Mildura 4 July 2013) Ms Chapman (chair, Citrus Australia Ltd) stated: “It was only last February

		that processors were out there paying \$700 to \$750 per tonne for juicing fruit. Those prices are not even heard of. That was the same year I was selling my navels for \$200 to \$250 a tonne.” Can Citrus Australia Ltd advise of the names of any processors who actually paid growers \$700 to \$750 per tonne for juicing fruit last February, to whom it was offered and for what period of time the offer was valid? Can Citrus Australia Ltd further advise if there were any particular fruit quality requirements growers had to meet in order to obtain \$700-750 per tonne?
Response Q20		Citrus Australia cannot name the processors or to whom it was offered due to commercial confidentiality. However we understand that prices between \$500 and \$700 were offered verbally to growers in the Riverina and Sunraysia areas for a short time early in 2012 due to a shortage of Valencia oranges.
Question 21	Riverina Citrus	In evidence (p18, Griffith 3 July 2013) it was stated that Citrus Australia Ltd had refused funds offered by Riverina Citrus for promotional purposes. If this is the case, can Citrus Australia Ltd advise why it did not accept these funds, and advise the difference between these funds and those provided by Queensland mandarin growers that were accepted by Citrus Australia Ltd?

Response Q21	In its first year of operation Citrus Australia received an attractive funding proposal by Riverina Citrus, to be executed through a service agreement, similar to the one previously enjoyed by Australian Citrus Growers Inc under the previous federated multi-structured model . The Citrus Australia Board considered the proposal at length and agreed not to accept the offer mainly due to the need to focus on building relationships and accountability direct with growers and as governed by the new Citrus Australia Constitution. Citrus Australia was happy to continue working under informal arrangements. In the 2011 season which presented as a very challenging one for growers due to the large navel orange crop and record exchange rates, Citrus Australia facilitated meetings with Riverina Citrus, Murray Valley Citrus Board and the SA Citrus Board to work on an additional orange promotion campaign to assist the industry. As part of these discussions, and knowing that at least 2 of the 3 state boards carried significant reserves, Citrus Australia sought a small contribution from each to implement the additional orange promotion campaign. The email which was sent on 24 June 2011 to 29 recipients including the Chairs and CEO's of the 3 state boards is reproduced below: <i>Thank you for your participation in Tuesday's teleconference or input into this issue.</i> <i>Whilst we covered many issues – short and longer term, and some out of our control such as the Aussie dollar – we generally agreed to progress a short-term burst of activity addressing industry, consumer and government which is outlined briefly below:</i> <i>Issue Management Strategy and Plan 2011 Navel Season</i> <i><u>Executive Summary</u></i> <i>Situation Analysis</i> <i>The serious challenges facing the industry this season are well understood but have not been widely or strategically communicated. As an industry, citrus is competing for 'share of voice' with other rural and food security stories including:</i> • <i>Suspension of Australia's live exports to Indonesia, and potentially to other markets</i> • <i>The results of storms and floods following a long period of drought</i> • <i>The clean-up following these storms and floods – and particularly the recovery of Queensland</i> • <i>Limited supply and high prices for fruit and vegetables grown in flood affected areas</i> <i>In order for the citrus industry to get itself noticed in this noisy market, it will be important to:</i> • <i>Take a pro-active approach – particularly to media engagement</i> • <i>Repeat clear messages that are agreed and used by both national and regional spokespeople</i> • <i>Offer the media strong, multiple story angles and opportunities – interviews with affected growers and packers,</i>

attractive visuals, and key facts and figures that credibly highlight the issues.

Recommended Strategy

- *Conduct a short-term, demand creation campaign (see Clemenger PR plan, attached).*
 - *Managed by Simon West of Citrus Australia and implemented by Clemenger PR (Brisbane) with the cooperation of representative grower spokespeople from each region.*
 - *Also include quotes and interview opportunities for Judith Damiani, CEO of Citrus Australia.*
- *In parallel with the demand creation campaign, run an education campaign that highlights the challenges facing the industry and what needs to be done to address them.*
- *In this education campaign, avoid going to market with an alarmist message that may:*
 - *Invite negative comparisons with other industries or states that are also facing challenges*
 - *Result in ongoing media and Government focus on the negatives*
 - *Invite a knee-jerk reaction from Government or regulators.*
- *Citrus Australia can increase the reach and effectiveness of messaging about the high Australian dollar by aligning itself with the Australian Institute of Export (<http://www.aiex.com.au/>). Briefing meeting with them so they can effectively communicate on the citrus industry as part of their ongoing commentary on the impact of the Australian dollar on export earnings. Also request permission to include quotes from a director of the Institute in Citrus Australia media releases.*

Recommended Key Messages by Target Audience

Stakeholders	Key Messages	Channels
Australian Consumers	• See Clemenger PR plan (attached)	
State and Federal Government, government agencies, regulatory authorities and financial institutions.	• Difficulties facing the industry this season - The reasons for them - Factors within our control vs. those global in scope • Importance of the citrus industry - A major food exporter under threat. If the industry fails, Australia will become a net importer in this category. • The impact on individual growers,	• Face-to-face briefings of: ◦ Local members ◦ State ministers ◦ Federal ministers ◦ Policy advisor ◦ Directors of government agencies ◦ Directors of regulatory authorities • Letters and briefing kits to industry analysts, economists

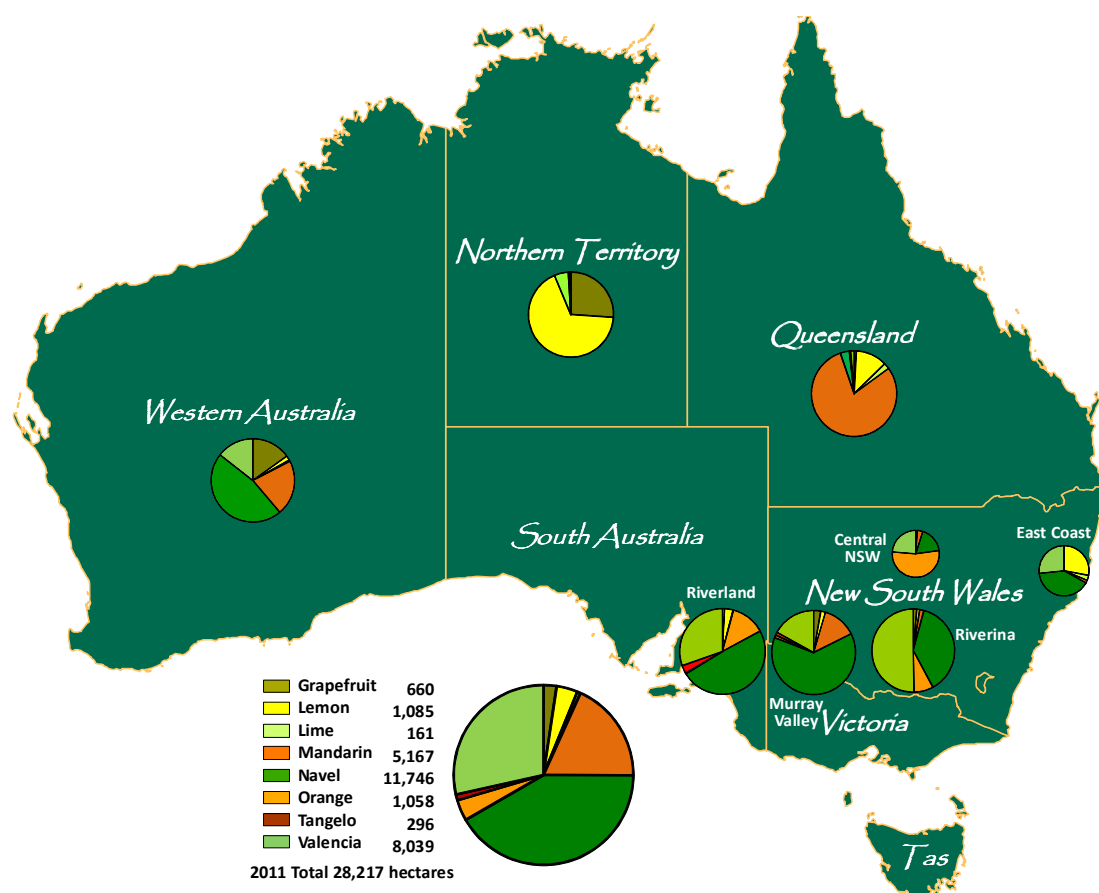
		<table> <tr> <td></td><td> <i>packers, and other points in the value chain e.g. packing materials, freight handlers, irrigation, ag. equipment, etc.</i> - <i>Knock-on effect to rural, regional, state and national economies.</i> - <i>Also affect Govt. depts and agencies e.g. Research, Dept. Primary Industry, AQIS.</i> </td><td> <i>and agribusiness managers of key financial institutions</i> • <i>1:1 interviews with selected media reaching these audiences</i> </td></tr> </table>		<i>packers, and other points in the value chain e.g. packing materials, freight handlers, irrigation, ag. equipment, etc.</i> - <i>Knock-on effect to rural, regional, state and national economies.</i> - <i>Also affect Govt. depts and agencies e.g. Research, Dept. Primary Industry, AQIS.</i>	<i>and agribusiness managers of key financial institutions</i> • <i>1:1 interviews with selected media reaching these audiences</i>
	<i>packers, and other points in the value chain e.g. packing materials, freight handlers, irrigation, ag. equipment, etc.</i> - <i>Knock-on effect to rural, regional, state and national economies.</i> - <i>Also affect Govt. depts and agencies e.g. Research, Dept. Primary Industry, AQIS.</i>	<i>and agribusiness managers of key financial institutions</i> • <i>1:1 interviews with selected media reaching these audiences</i>			
		Attached: Clemenger PR (who are doing the PR work for Australian Oranges and Mandarins) have quickly put together a proposal which we recommend to you. We are working with them on some final costings but at a minimum the cost is \$10,000 for a 2 month campaign. We are seeking your contribution to this additional PR campaign. For example: • <i>Riverina \$4000</i> • <i>Murray Valley \$4,000</i> • <i>SA \$4,000</i> • <i>Citrus Australia will contribute by co-ordinating the campaign and ensuring weekly reports to this group.</i> Your response and comments will be appreciated. I'm not sure if I have reached everyone who was on the teleconference – please feel free to pass it on! Regards Judith Voluntary contributions of \$24,000 were subsequently received from other Victorian and South Australian organisations and were directly deposited with HAL. No financial contributions were received from any of the 3			

		state boards, despite follow up actions. Citrus Australia went on to mount its biggest orange PR campaign ever, which included capital city orange hand-outs during Aussie Orange Week – the Citrus Australia Board, staff and industry/HAL volunteers all participating. Over \$1,000,000 worth of PR and advertising was secured through this nationally coordinated effort during the campaign.
Question 22	Biosecurity	In evidence (p65, Mildura 4 July 2013) Committee Chair Senator Heffernan asked Ms Damiani (chief executive officer Citrus Australia Ltd): <i>CHAIR: What is the estimated damage if there is an incursion of HBL [Huanglongbing], if you have a plan? It is about \$8 million for the cattle industry for foot and mouth. What is yours?</i> <i>Ms Damiani: I think it depends on what scenario you use. Where is it found? When is it found?</i> <i>CHAIR: If it comes in on a cyclone, it might go to Moree or wherever—I don't know—there would be a contingency about borders and a whole lot of rigmarole around that. It really would not matter much. Have you got a contingency plan if it comes in from wherever? I do not know where it is going to come in from. The department did not even seem to know where it was, which surprised me, and they did not seem to know whether there was a contingency plan. Have you talked to the department about this? Who organised the contingency plan?</i> <i>Ms Damiani: We work through Plant Health Australia on any contingency plans. We have been working through them. We have also utilised the expert experience from a number of entomologists and pathologists.</i> <i>CHAIR: Could you table the contingency plan.</i> <i>Ms Damiani: Yes, I would be happy to.</i> Can Citrus Australia Ltd provide a copy of the above-mentioned contingency plan they have prepared in conjunction with Plant Health Australia?
Response Q22		Yes, attached



Know-how for Horticulture™

2011 National Citrus Plantings Database



Final Report
2011

SunRISE 21 Inc.
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ABN 81 397 614 997
54 Lemon Ave MILDURA

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Disclaimer

This report was prepared by SunRISE 21 Incorporated in consultation with Citrus Australia Ltd, regional citrus organisations and individual citrus growers. Information contained herein is based on data and information from a range of sources. Whilst SunRISE 21 has endeavoured to correctly interpret, analyse and present the information, SunRISE 21 Inc. does not warrant that this report is definitive nor free of error and does not accept liability for any loss caused or arising from use of or reliance upon information contained herein.

No person should act on the basis of the contents of this publication, whether as to matters of fact or opinion or other content, without first obtaining specific, independent professional advice in respect of the matters set out in this publication.

Contents

Acknowledgements	6
Executive Summary	7
Method	9
1. Results.....	12
1.1 National Citrus.....	12
1.1.1 National citrus summary	12
1.1.2 Australian citrus by region	15
1.2 Riverina	17
1.2.1 Riverina citrus.....	17
1.2.2 Riverina 2011 citrus varieties	21
1.2.3 Riverina change since 2003.....	23
1.3 Murray Valley	25
1.3.1 Murray Valley citrus.....	25
1.3.2 Murray Valley 2011 citrus varieties	29
1.3.3 Murray Valley change since 2003	32
1.4 Riverland	35
1.4.1 Riverland citrus	35
1.4.2 Riverland 2008 citrus varieties.....	39
1.4.3 Riverland change 2003 to 2008.....	42
1.5 Queensland	44
1.5.1 Queensland citrus	44
1.5.2 Queensland 2011 citrus varieties.....	49
1.5.3 Queensland change since 2003.....	50
1.6 Western Australia	52
1.6.1 Western Australia citrus.....	52
1.6.2 Western Australia 2011 citrus varieties.....	56
1.6.3 Western Australia change since 2003	58
1.7 Central NSW	60
1.7.1 Central NSW citrus	60
1.7.2 Central NSW 2011 citrus varieties	64
1.7.3 Central NSW change since 2003	65
1.8 East Coast NSW.....	66
1.8.1 East Coast NSW citrus	66
1.8.2 East Coast NSW 2011 citrus varieties.....	70
1.9 Northern Territory	72
1.9.1 Northern Territory citrus.....	72
1.9.2 Northern Territory 2011 citrus varieties	76
1.9.3 Northern Territory change since 2003.....	76
References	77
Appendix A – Sample property crop plan.....	78
Appendix B – Standard crop database fields	79
Appendix C – National 2011 citrus varieties list.....	81
Appendix D – National citrus varieties change 2003 to 2011	85

List of Maps

Map 1 – Riverina citrus map	20
Map 2 – Murray Valley citrus map	28
Map 3 – Riverland citrus map	38
Map 4 – Queensland citrus map	48
Map 5 – Western Australia citrus map	55
Map 6 – Central NSW citrus map	63
Map 7 – East Coast NSW citrus map	69
Map 8 – Northern Territory citrus map.....	75

List of Tables

Table 1 – 2011 citrus per region.....	8
Table 2 – 2011 citrus capture by region.....	9
Table 3 – National citrus 2003 to 2011	13
Table 4 – National citrus property size	14
Table 5 – Citrus 2003 to 2011 per region.....	15
Table 6 – Citrus properties by region.....	16
Table 7 – Riverina citrus 2003 to 2011.....	18
Table 8 – Riverina dominant rootstock and irrigation type	19
Table 9 – Riverina citrus properties	19
Table 10 – Murray Valley citrus 2003 to 2011	26
Table 11 – Murray Valley dominant rootstock and irrigation type.....	27
Table 12 – Murray Valley citrus properties.....	27
Table 13 – Riverland citrus 2003 to 2008.....	36
Table 14 – Riverland dominant rootstock and irrigation type	37
Table 15 – Riverland citrus properties	37
Table 16 – Queensland citrus 2003 to 2011.....	45
Table 17 – Queensland dominant rootstock and irrigation type	47
Table 18 – Queensland citrus properties	47
Table 19 – Western Australia citrus 2003 to 2011.....	53
Table 20 – Western Australia dominant rootstock and irrigation type	54
Table 21 – Western Australia citrus properties	54
Table 22 – Central NSW citrus 2003 to 2011	61
Table 23 – Central NSW dominant rootstock and irrigation type.....	62
Table 24 – Central NSW citrus properties.....	62
Table 25 – East Coast NSW citrus 2003 to 2011	67
Table 26 – East Coast NSW dominant rootstock and irrigation type.....	68
Table 27 – East Coast NSW citrus properties	68
Table 28 – Northern Territory citrus 2003 to 2011.....	73
Table 29 – Northern Territory dominant rootstock and irrigation type	74
Table 30 – Northern Territory citrus properties	74

List of Figures

Figure 1 – National citrus	12
Figure 2 – Riverina citrus	17
Figure 3 – Murray Valley citrus	25
Figure 4 – Queensland citrus.....	44
Figure 5 – Western Australia citrus.....	52
Figure 6 – Central NSW citrus	60
Figure 7 – East Coast NSW citrus.....	66
Figure 8 – Northern Territory citrus.....	72

Acknowledgements

The 2011 National Citrus Plantings Database (2011 NPD) was commissioned by Citrus Australia Limited. Funding was administered by Horticulture Australia Limited through the Citrus Research and Development Levy under project code CT10035.

Accuracy of the planting statistics in this report is dependent on input from citrus growers, and over 740 growers across Australia are to be acknowledged for their time and consideration in returning the 2011 census.

The following agencies and personnel are acknowledged for their collaboration in compiling the 2011 NPD.

Murray Valley Citrus Board

Hugh Flett, Chief Executive
Mary Cannard, Industry Development Officer
Deb Scott, Office Administrator

2011 aggregated planting statistics for 477 Murray Valley citrus growers



Riverina Citrus

Dominic Testoni, Chief Executive Officer
Melanie Garbett, Industry and Promotions Manager

2008-2011 aggregated planting statistics for 474 Riverina citrus growers



Northern Territory Primary Industry and Fisheries

Megan Connelly, Extension Officer

Coordination of NT grower surveys



Citrus Australia Ltd

Andrew Harty, General Manager Market Development
Nathan Hancock, Manager Market Information &
Domestic Market Liaison

Coordination of Western Australia, Queensland, Central NSW and East Coast NSW grower surveys



Executive Summary

The 2011 National Citrus Plantings Database (2011 NPD) was commissioned by Citrus Australia Limited. Funding was administered by Horticulture Australia Limited (HAL) through the Citrus Research and Development Levy.

The 2011 NPD (HAL project code CT10035) follows on from the 2003 NPD (CT02033) and 2008 NPD (CT07055) which have all been completed by SunRISE 21 Inc. using spatial information technologies.

Aim of the project

The project was undertaken to update the 2008 NPD and provide planting statistics and trends (2003 to 2011) across the Australian citrus industry. This information allows analysis of industry production trends, and strengthens decision making related to market development.

The project has linkages to Citrus Industry Strategic Plan imperatives:

- Improve industry communication and information systems; and
- Improve industry competitiveness

It also aligns with three program areas recommended in the Industry Development Needs Assessment:

- Market development;
- Information and data management; and
- Communications

Outcomes

The citrus planting mapping and databases assist the industry at grower, regional and national levels with:

- Short and long term crop forecasting;
- Decision making by growers on future plantings and tree removal;
- Planning for logistical requirements throughout the supply chain; and
- Information for processors, wholesalers, retailers and exporters on future market development directions.

Although not a prime aim of the project, the NPD also provides a record of citrus planting locations for biosecurity purposes.

Status of regional information

The three regional boards; Murray Valley, Riverina and South Australia manage their region's grower and plantings databases, encompassing 76% of Australia's citrus. At the time of compiling this report the status of aggregated statistics from the regional boards for input to the 2011 NPD was as follows:

- Murray Valley 2011 statistics were complete and are included in this report
- Riverina 2011 statistics were 50% complete. Figures in this report are compiled from aggregated data comprising 50% 2011 data and 50% 2008 data
- South Australia 2011 statistics were unavailable. To more closely approximate a national total 2008 Riverland data from the 2008 NPD has been used where national totals or summaries are presented.

Background

Analysis of the 2003, 2008 and 2011 citrus databases identifies change over an eight year period encompassing drought and low water allocations, floods, containment of a citrus canker outbreak, globalisation of markets and a rigorous trading environment. In this period, over 410 citrus growers (18%) exited the citrus industry. And while well over 5,000 hectares of Australia's citrus has been removed in the past five years 3,150 hectares, which does not include Riverina and Riverland non-bearing areas, has been planted or reworked.

Results overview

The 2011 NPD comprises 28,217 hectares of citrus (12.5 million trees) from 1,867 citrus properties.

The following table shows citrus area and property numbers per region, custodianship of the regional database and percentage of area surveyed. Area surveyed is the area that the 2011 variety or sub-category (such as navel) is recorded. It is the area of 2011 grower surveys plus areas of earlier grower surveys where it is visually interpreted from imagery that no change has since occurred.

Table 1 – 2011 citrus per region

Region	Properties mapped		Citrus mapped		% of area surveyed	Database custodian
	number	% of total	ha	% of total		
Riverina NSW	474	25%	8,800	31%	<i>not available</i>	Riverina Citrus
Murray Valley	477	26%	6,580	23%	97%	MVCB
Riverland	557	30%	6,303	22%	<i>not available</i>	SA CIDB
Queensland	84	4%	3,591	13%	99%	CAL
Western Australia	184	10%	1,561	6%	93%	CAL
Central NSW	15	1%	875	3%	99%	CAL
East Coast NSW	69	4%	368	1%	96%	CAL
Northern Territory	7	0%	137	0%	100%	CAL
Total	1,867	100%	28,217	100%		
Average	15.1 ha per property					

Note: 2011 figures for Riverland are unavailable and 2008 figures have been used for 2011
2011 figures for Riverina have only been updated for 50% of growers since 2008

Method

The project methodology is based on GIS (Geographical Information System) technology comprising ESRI ArcGIS software used in conjunction with orthophoto imagery to map citrus plantings. This provides accurate areas (hectares) of citrus and a user-friendly spatial format for citrus growers to record, and update, their planting details of; variety, tree numbers, age, rootstock, inter-plantings and irrigation method. A sample 'crop plan' is shown in Appendix A.

The system maps citrus plantings to the individual crop patch level and stores details on citrus variety, rootstock, year planted, number of trees, area (hectares) and inter-plantings. Details on property ownership are also collected. See Appendix A for a sample 'Property Crop Plan' and Appendix B for 'Crop Database Fields' and 'Property Database Fields'.

NPD tasks

There are five key activities in updating the National Plantings Database (NPD):

- Acquisition of the most recent, affordable, imagery (may include Google Earth)
- Preparation and mail-out of grower survey maps
- Grower surveys
- Data entry and mapping based on grower survey returns
- Analysis of the citrus mapping databases

The process and responsibility of undertaking these activities varied from region to region as summarised in Table 2.

Table 2 – 2011 citrus capture by region

Region	Imagery source	Survey maps	Grower surveys	Data entry	Planting statistics
Riverina NSW	2011 satellite imagery acquired by Riverina Citrus	Riverina Citrus	Riverina Citrus	Riverina Citrus	Riverina Citrus
Murray Valley VIC & NSW	2009 & 2011 orthophoto imagery acquired by MVCB, SR21 & partners	SunRISE 21 & MVCB	MVCB	SunRISE 21 & MVCB	SunRISE 21 & MVCB
Queensland	2009 SPOT imagery and 2010 Google Earth	SunRISE 21	SunRISE 21 and CAL	SunRISE 21	SunRISE 21
Western Australia	2010 Landgate Imagery, 2010 Google Earth, 2011 NearMap	SunRISE 21	SunRISE 21 and CAL	SunRISE 21	SunRISE 21
East Coast NSW	2010 Google Earth and 2010 NearMap	SunRISE 21	SunRISE 21	SunRISE 21	SunRISE 21
Central NSW	2010 and 2004 Google Earth	SunRISE 21 and CAL	SunRISE 21 and CAL	SunRISE 21	SunRISE 21
Northern Territory	2010 and 2006 Google Earth	SunRISE 21	SunRISE 21 & NT gov.	SunRISE 21	SunRISE 21

Orthophoto imagery

Orthophoto imagery is scale accurate, map referenced (i.e. with easting and northing coordinates) imagery processed from aerial photography or satellite imagery. The currency of available orthophoto imagery for each region varies considerably. For some regions, such as East Coast NSW, Google Earth provides free access to more recent satellite imagery and this has been used to check for visual changes to plantings. Where a visual change is identified, the mapping is edited to reflect the change which may be a new citrus patch, redeveloped citrus or citrus removed. Visual interpretation of the imagery provides information on citrus areas, estimates of tree numbers and sometimes the age of the planting and the irrigation method. It is only through grower surveys, however, that crucial details on varieties and rootstocks is captured.

The following is a sample of high resolution 2008 orthophoto imagery¹. It clearly identifies where drought and low water allocations are impacting on citrus.



citrus not irrigated

irrigated citrus

Planting Statistics

Regional planting statistics were generated using Microsoft Access software which was developed by Grant Hamence Software Design Pty Ltd specifically for the citrus mapping databases. This software tool is used by and licensed to the main citrus organisations, MVCB, Riverina Citrus, SACIDB and Citrus Australia Ltd.

It enables each of the regions to assign their own aliases to different citrus varieties; as each region and its growers often have different names and spelling for the same variety. A master citrus variety list was compiled in the 2003 NPD study; however it is in need of review and updating with many new varieties having since been planted.

New properties mapped

New properties not previously mapped in the 2003 and 2008 NPD projects, were mapped this year where Google Earth, NearMaps or Western Australia's Landgate imagery was available:

- Queensland – nine new properties including six at Mareeba and one at Elliott
- Central NSW - five new properties (516 ha) mapped at Moree, Forbes and Gunnedah
- Western Australia – six new properties

Where new areas are located and mapped, the previous mapping, i.e. 2003 and 2008 mapping, is back-filled, if relevant to the age of the plantings, to maintain consistency in monitoring trends over time.

¹ Image sourced from SAMRIC – South Australian Murray-Darling Basin Resource Information Centre Inc.

Changes to 2003 NPD and 2008 NPD statistics

For over 3,000 hectares of citrus mapped in the 2003 NPD and 1,450 hectares mapped in the 2008 NPD, the varieties were unknown due to the property owner not having been surveyed.

Many of these properties have since been surveyed and the earlier citrus mapping has been amended (back-filled) to include relevant details. Hence, the 2003 and 2008 citrus mapping has been improved and figures in this report may not cross reference with those in the 2003 and 2008 NPD reports.

Data Limitations

The areas (hectares) of plantings have been derived from scale accurate, high resolution (generally less than half metre pixel) imagery. This provides accurate areas where the terrain is relatively flat, but areas calculated for extensive citrus plantings on hilly terrain may be less than the actual terrain surface area.

Tree numbers are less reliable than the hectares as they are derived from a range of sources; counts from imagery, calculation from row and plant spacings or specified by the grower. Tree numbers should be treated as estimates only.

Whilst citrus in all the main citrus regions in Australia has been mapped, there are scattered properties that aren't mapped, such as lime growing properties along the Queensland coast ; therefore figures in this report should not be considered as absolute.

The 2011 national planting statistics presented are NOT complete in that they have been compiled from 2008 Riverland data (2011 data was not available) and 2008-2011 Riverina data where fifty percent of the 2008 Riverina data has been updated to 2011.

1. Results

1.1 National Citrus

The 2011 national planting statistics presented are NOT complete in that they have been compiled from 2008 Riverland data (2011 data was not available) and 2008-2011 Riverina data where fifty percent of the 2008 Riverina data has been updated to 2011. As such, the national total comprises 28,217 hectares of citrus (an estimated 12.49 million trees); with 95% of this area recorded to the variety level.

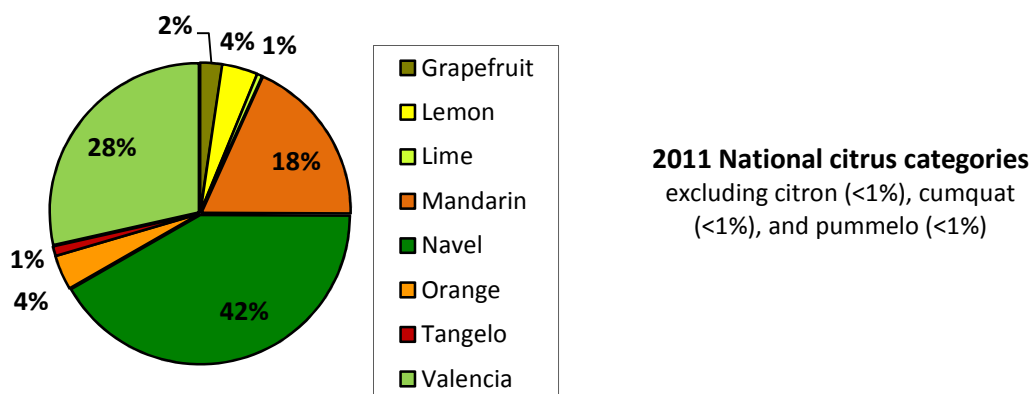
A listing of all varieties mapped with areas and tree numbers is provided in Appendix C.

1.1.1 National citrus summary

In summary for Australian citrus:

- In 2011; 28,217 hectares of citrus (12.49 million trees) across 1,867 citrus properties were mapped in the main citrus growing regions of Australia
- The area of citrus declined from 29,885 hectares in 2003 to 27,810 hectares in 2008, then increased to 28,217 hectares in 2011
- The number of citrus trees declined from 12,494,858 in 2003 to 12,196,866 in 2008, then increased to 12,490,205 trees in 2011
- Valencia oranges are the dominant plantings (27%) followed by Washington and Late Lane navels (23%) then Imperial mandarins (6%). (See Appendix C)
- While the number of citrus growers declined from 2,276 in 2003 to 1,963 in 2008 and to 1,867 in 2011 (a 18% decline), the average citrus area per property increased from 13.1 in 2003 to 14.2 in 2008 and to 15.1 hectares in 2011
- The average trees /ha increased from 418 in 2003 to 443 in 2011
- Australian citrus is predominantly grown on a Trifoliata rootstock and irrigated with low level sprinklers

Figure 1 – National citrus



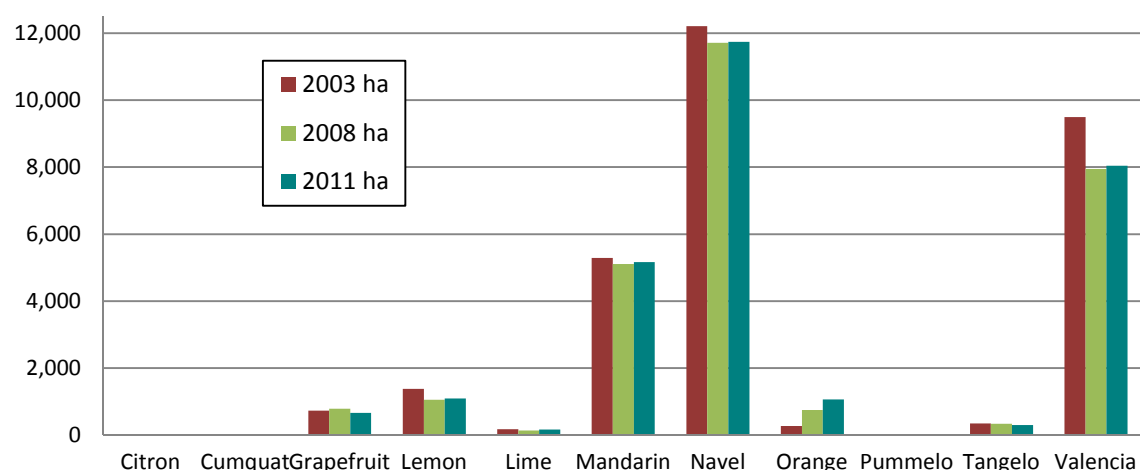
Australian citrus 2003 to 2011

The area of Australian citrus declined from 29,885 hectares in 2003 to 27,810 hectares in 2008 then increased slightly to 28,217 hectares in 2011. The overall change from 2003 to 2011 is a 6% decline in area planted (-1,668 hectares) as shown in Table 3.

Apart from some minor plantings of cumquat and citron (Buddha's Hand), the only citrus category that has increased in area since 2003 is 'Orange', largely influenced by plantings of Salustiana and Hamlin sweet oranges.

Table 3 – National citrus 2003 to 2011

Category	2003		2008		2011		Change 2003-2011	
	ha	1,000 trees	ha	1,000 trees	ha	1,000 trees	ha	1,000 trees
Citron	0	0	<1	0.05	<1	0.05	+<1	+0.05
Cumquat	0	0	0	0	1	0.04	+1	+0.04
Grapefruit	725	295	777	305	660	265	-64	-30
Lemon	1,374	572	1,052	415	1,085	430	-289	-142
Lime	165	71	127	50	161	65	-4	-6
Mandarin	5,286	2,375	5,101	2,427	5,167	2,496	-119	+121
Navel	12,215	5,285	11,714	5,271	11,746	5,288	-468	+3
Orange	268	162	743	461	1,058	658	+791	+496
Pummelo	18	6	21	7	3	2	-14	-4
Tangelo	342	174	329	168	296	151	-46	-23
Valencia	9,493	3,556	7,947	3,091	8,039	3,136	-1,454	-420
Total	29,885	12,495	27,810	12,197	28,217	12,490	-1,668	-5
							-6%	0%
Average	418 trees/ha		439 trees/ha		443 trees/ha			



Note: A total of 5% of citrus categories are unknown. A linear extrapolation was applied on a region by region basis to account for unknown citrus categories.

Note: 2011 figures for Riverland are unavailable and 2008 figures have been used for 2011
2011 figures for Riverina have only been updated for 50% of growers since 2008

Australian dominant citrus varieties

The national dominant citrus variety remains Valencia, followed by Washington and Late Lane navels.

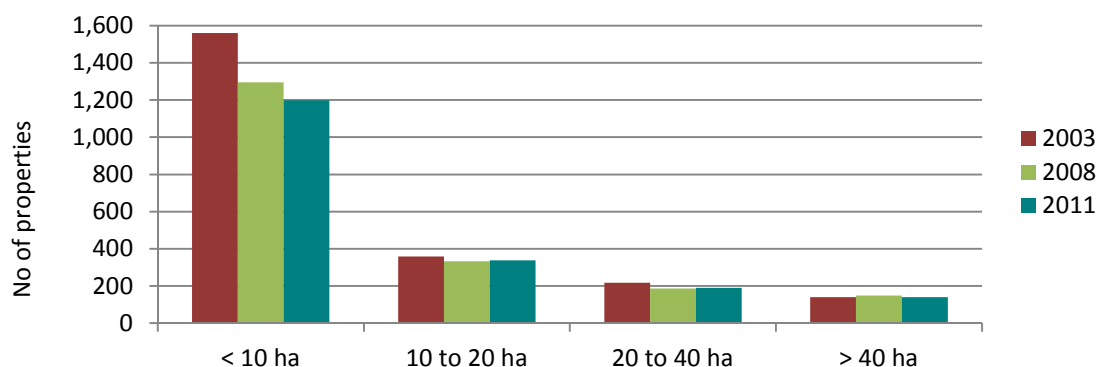
	Dominant variety		
	2003	2008	2011
1	Valencia	Valencia	Valencia
2	Washington	Washington	Washington
3	Late Lane	Late Lane	Late Lane
4	Imperial	Imperial	Imperial
5	Navelina	Murcott	Murcott

Australian citrus properties

While the number of citrus growers declined by 409 between 2003 and 2011; the average property size increased from 13.1 to 15.1 hectares of citrus as shown in the following table.

Table 4 – National citrus property size

Property size (citrus area)	Number of properties			Change 2003 to 2011	
	2003	2008	2011	properties	% of 2003
< 10 ha	1,560	1,294	1,198	-362	-16%
10 to 20 ha	358	333	338	-20	-1%
20 to 40 ha	217	187	190	-27	-1%
> 40 ha	141	149	141	0	0%
Total properties	2,276	1,963	1,867	-409	-18%
Average property size (ha of citrus)	13.1	14.2	15.1		



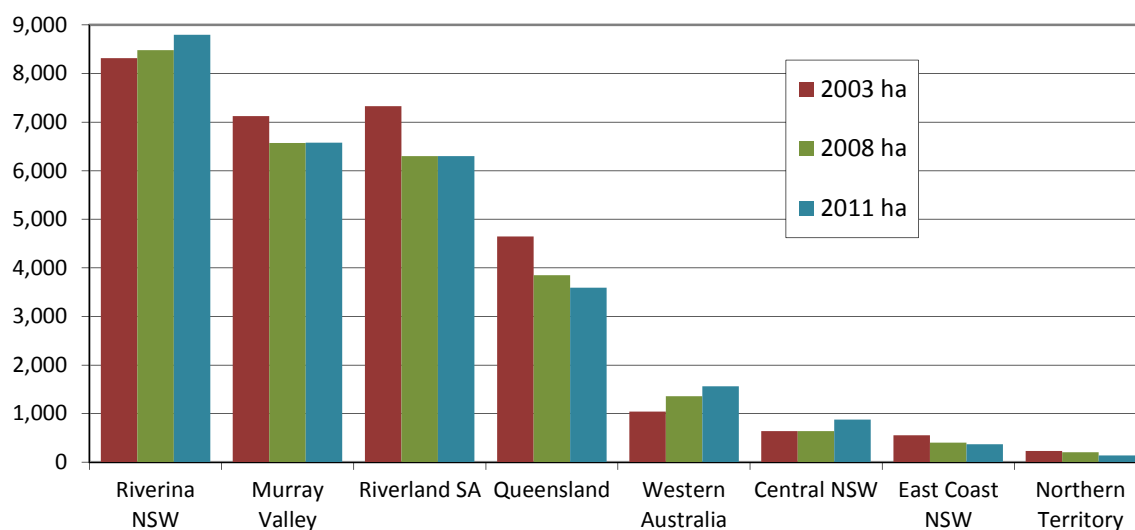
Note: 2011 figures for Riverland are unavailable and 2008 figures have been used for 2011
2011 figures for Riverina have only been updated for 50% of growers since 2008

1.1.2 Australian citrus by region

Australian citrus has declined by 1,669 hectares (4,600 trees) since 2003. Citrus in the Riverina, Western Australia and Central NSW has increased since 2003, while Murray Valley, Riverland, Queensland, East Coast NSW and Northern Territory have all had a reduction in citrus plantings.

Table 5 – Citrus 2003 to 2011 per region

Region	2003		2008		2011		Change 2003-2011	
	ha	1,000 trees	ha	1,000 trees	ha	1,000 trees	ha	1,000 trees
Riverina NSW	8,317	3,314	8,480	3,457	8,800	3,586	+483	+272
Murray Valley	7,128	3,144	6,569	3,084	6,580	3,095	-547	-49
Riverland SA	7,327	2,917	6,303	2,747	6,303	2,747	-1,024	-170
Queensland	4,645	1,904	3,850	1,561	3,591	1,483	-1,054	-421
Western Australia	1,042	464	1,356	672	1,561	813	+519	+350
Central NSW	638	344	643	373	875	516	+237	+172
East Coast NSW	555	325	403	231	368	202	-187	-123
Northern Territory	233	83	206	73	137	48	-96	-35
Total	29,885	12,495	27,810	12,197	28,216	12,490	-1,669	-4.6
Average	418 trees/ha		439 trees/ha		443 trees/ha			



Note: 2011 figures for Riverland are unavailable and 2008 figures have been used for 2011
2011 figures for Riverina have only been updated for 50% of growers since 2008

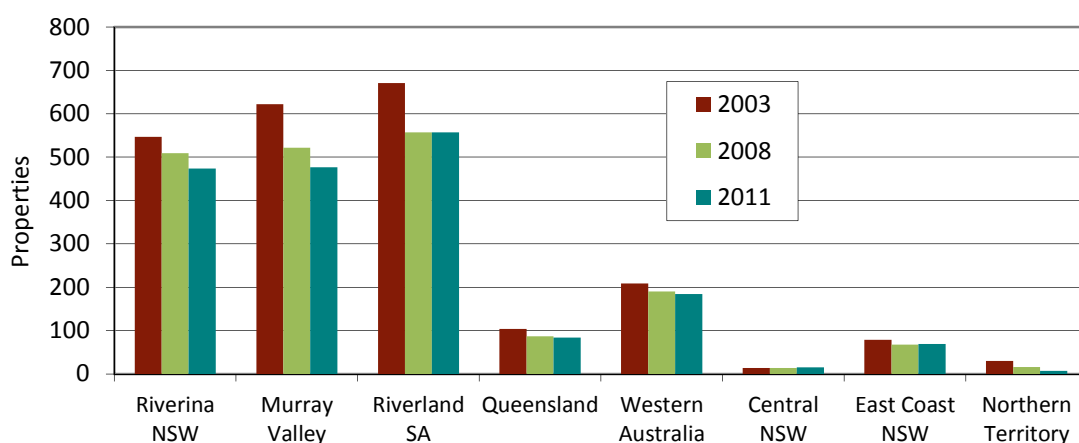
Trees per hectare

Citrus properties by region

Citrus properties have declined in all regions other than Central NSW where the additional properties mapped at Moree, Forbes and Gunnedah have increased the region by one.

Table 6 – Citrus properties by region

Region	2011			Change 2003 - 2011	
	No. properties	% of Total	Ave. citrus ha/property	No. properties	% of Region
Riverina	474	25%	18.6	-73	-13%
Murray Valley	477	26%	13.8	-145	-23%
Riverland	557	30%	11.3	-114	-17%
Queensland	84	4%	42.7	-20	-19%
Western Australia	184	10%	8.5	-25	-12%
Central NSW	15	1%	58.3	+1	+7%
East Coast NSW	69	4%	5.3	-10	-13%
Northern Territory	7	0%	19.6	-23	-77%
Total	1,867	100%	15.1	-409	-18%



Note: 2011 figures for Riverland are unavailable and 2008 figures have been used for 2011
2011 figures for Riverina have only been updated for 50% of growers since 2008

Australian non-bearing citrus by region

Region	2011 ha	Non-bearing	% of Region	Main non-bearing varieties
Riverina	8,800	unavailable		
Murray Valley	6,580	746	11%	Afourer, Imperial, Late Lane
Riverland	6,303	unavailable		
Queensland	3,591	1,217	34%	Murcott, Murcott LS, Imperial
Western Australia	1,561	630	40%	Late Lane, Washington, Newhall
Central NSW	875	496	57%	Salustiana, Hamlin, McMahon
East Coast NSW	368	13	4%	Eureka
Northern Territory	137	45	33%	Eureka, Tahitian
Total	28,217	3,147	11%	

Note: non-bearing refers to citrus plantings after 2005 or reworks after 2008

1.2 Riverina

Grower surveys, data entry and planting statistics for the Riverina region were undertaken by Riverina Citrus. The mapping was based on 2011 satellite imagery acquired by Riverina Citrus and partner agencies.

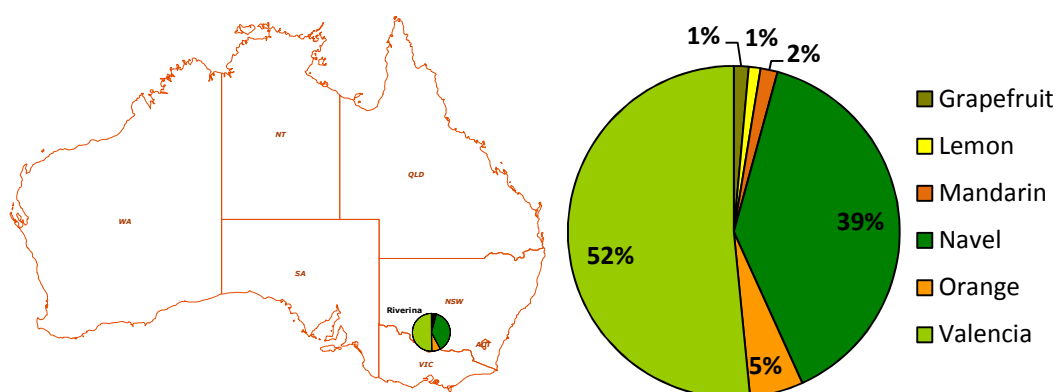
At the time of compiling this report Riverina Citrus had not completed updating its 2008 citrus mapping to 2011. Hence, the '2011' statistics presented in this report comprise 50% of 2011 citrus and 50% of 2008 citrus yet to be updated.

1.2.1 Riverina citrus

In summary for Riverina citrus:

- In 2011; 8,800 hectares of citrus (3,586,241 trees) across 513 citrus properties were mapped
- Riverina predominantly grows Valencia oranges
- The area of citrus increased from 8,317 hectares in 2003 to 8,480 hectares in 2008 and 8,800 hectares in 2011
- The number of citrus trees increased from 3,313,777 in 2003 to 3,456,661 in 2008 to 3,586,241 in 2011
- The number of citrus growers declined from 547 in 2003 to 509 in 2008 and increased to 513 in 2011; the average citrus area per property increased from 15.2 hectares in 2003 to 16.7 hectares in 2008 and 17.2 hectares in 2011
- Riverina citrus is predominantly drip irrigated and grown on a Trifoliata rootstock

Figure 2 – Riverina citrus



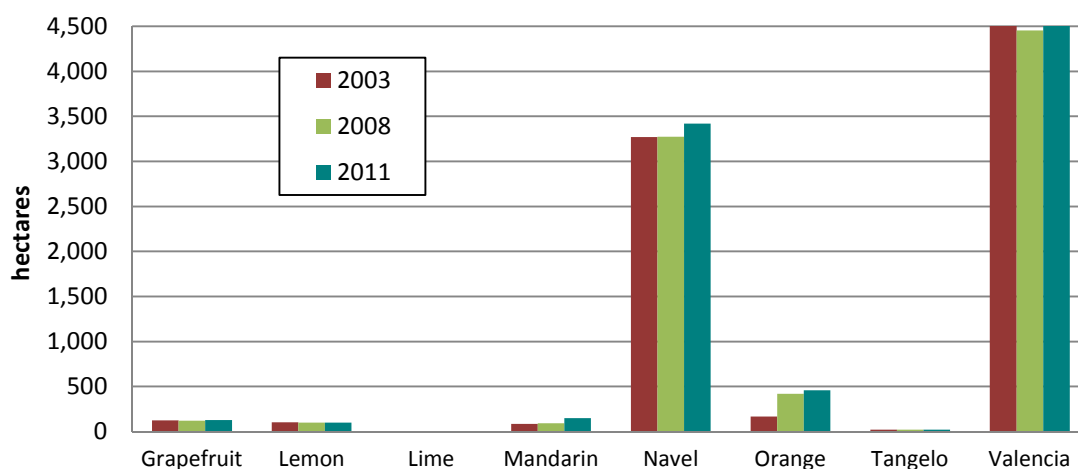
2011 Riverina citrus categories
(excluding lime (<1%) and tangelo (<1%))

Riverina citrus 2003 to 2011

The area of citrus in the Riverina has increased from 8,317 hectares in 2004 to 8,480 hectares in 2008 then to 8,800 hectares in 2011. The overall change from 2003 to 2011 is a 6% increase in area planted (483 hectares) and an 8% increase in tree numbers (272,464 trees) as shown in Table 7.

Table 7 – Riverina citrus 2003 to 2011

Category	2003		2008		2011		Change 2003-2011	
	ha	trees	ha	trees	ha	trees	ha	trees
Citron	-	-	-	-	-	-	-	-
Cumquat	-	-	-	-	-	-	-	-
Grapefruit	125	48,303	120	46,910	126	51,263	+1	+2,960
Lemon	102	39,779	98	38,016	101	41,072	-2	+1,293
Lime	1	682	2	1,428	3	1,609	+1	+927
Mandarin	86	33,320	91	38,530	147	72,665	+61	+39,345
Navel	3,270	1,329,567	3,275	1,343,702	3,420	1,399,124	+150	+69,557
Orange	166	110,582	417	256,692	458	278,742	+292	+168,160
Pummelo	-	-	-	-	-	-	-	-
Tangelo	21	7,646	20	7,618	21	7,673	0	+27
Valencia	4,546	1,743,897	4,455	1,723,765	4,525	51,263	-21	-9,805
Total	8,317	3,313,777	8,480	3,456,661	8,800	3,586,241	+483 +6%	+272,464 +8%
Average	398 trees/ha		408 trees/ha		408 trees/ha			



Note: 6% of citrus categories are unknown. A linear extrapolation was applied to account for the 6%. Tree numbers are estimates from a range of sources; grower input, calculations & counts from imagery

Dominant variety

The dominant Riverina citrus variety was Valencia from 2003 to 2011.

Dominant variety			
	2003	2008	2011
1	Valencia	Valencia	Valencia
2	Washington	Washington	Washington
3	Late Lane	Late Lane	Late Lane
4	Navel <i>unspecified</i>	Navel <i>unspecified</i>	Navel <i>unspecified</i>
5	Navelina	Navelina	Navelina

Riverina citrus rootstocks, irrigation and properties

Riverina citrus is predominantly drip irrigated and grown on Trifoliata rootstock as shown in Table 8.

Table 8 – Riverina dominant rootstock and irrigation type

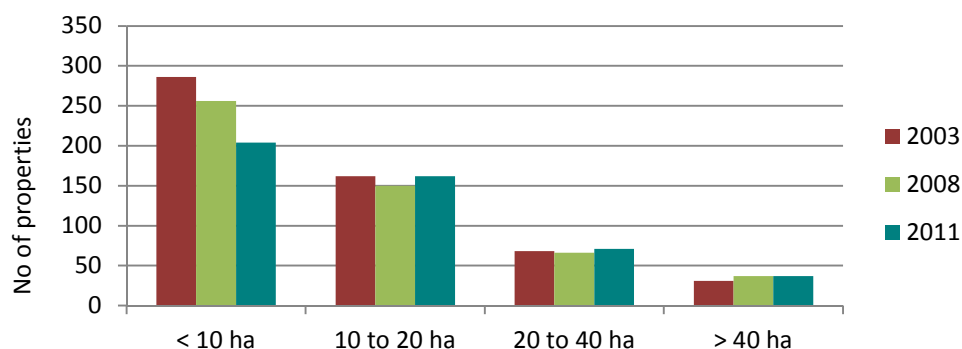
	2011 Trees/ha		Dominant rootstock 2011	Dominant irrigation		
	Non- bearing	bearing		2003	2008	2011
Grapefruit			Trifoliata	Drip	Drip	Drip
Lemon			Trifoliata	Drip	Drip	Drip
Lime			Citrange	Drip	Drip	Drip
Mandarin			Trifoliata	Mini sprinkler	Mini sprinkler	Mini sprinkler
Navel			Trifoliata	Drip	Drip	Drip
Orange			Trifoliata	Drip	Drip	Drip
Tangelo			Citrange	Mini sprinkler	Mini sprinkler	Mini sprinkler
Valencia			Trifoliata	Furrow	Furrow	Furrow - Drip
Total			Trifoliata	Furrow	Drip	Drip

Riverina citrus properties

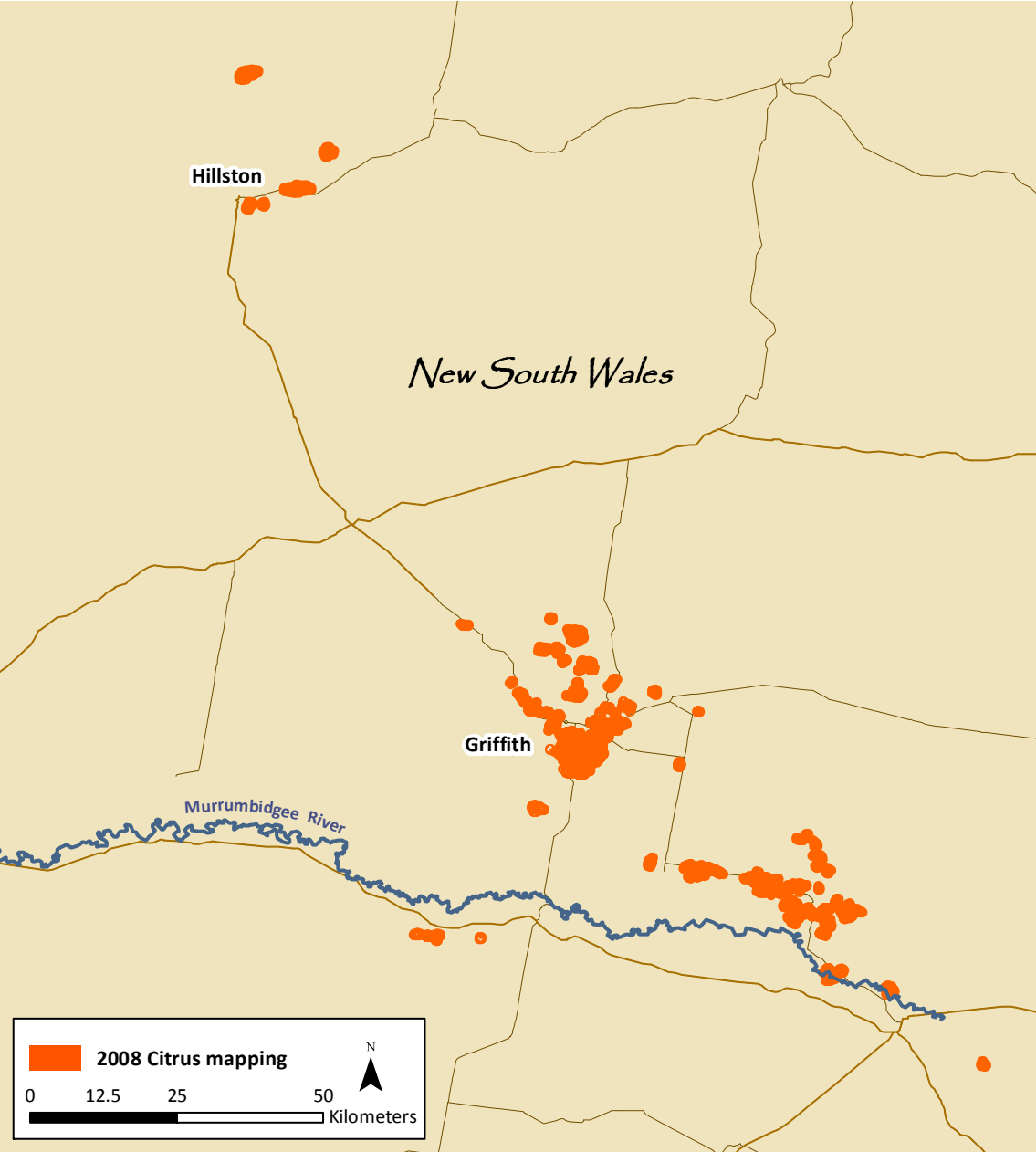
While the number of citrus growers declined by 34 between 2003 and 2011; the average property size increased from 15.2 to 17.2 hectares of citrus.

Table 9 – Riverina citrus properties

Property size (citrus area)	Number of properties			Change 2003 to 2011	
	2003	2008	2011	properties	% of 2003
< 10 ha	286	256	243	-43	-8%
10 to 20 ha	162	150	162	0	0%
20 to 40 ha	68	66	71	+3	+1%
> 40 ha	31	37	37	+6	+1%
Total properties	547	509	513	-34	-6%
Average property size (ha of citrus)	15.2	16.7	17.2		



Map 1 – Riverina citrus map



1.2.2 Riverina 2011 citrus varieties

CATEGORY		VARIETY	2011 HECTARES				
			Bearing	Non- bearing	Total		
Citrus		<i>not surveyed</i>			567	6%	
Grapefruit	Grapefruit white flesh	<i>unspecified grapefruit</i>			78	1%	
		Marsh			15	0%	
	Grapefruit pink & red flesh	Rio Red (Rio Star)			1	0%	
		Ruby (Red,Pink)			6	0%	
		Star Ruby			19	0%	
		Thompson (Eagle)			0	0%	
Lemon		<i>unspecified lemon</i>			56	1%	
		Eureka			36	0%	
		Lisbon			2	0%	
		Meyer			0	0%	
Lime		<i>unspecified lime</i>			1	0%	
		Tahitian (Persian)			1	0%	
Mandarin	Mandarin	<i>unspecified mandarin</i>			42	0%	
		Tangerine			1	0%	
	Mandarin early	Imperial			40	0%	
		Nules Clementine			4	0%	
		Okitsu Wase Satsuma			0	0%	
		<i>Satsuma unspecified</i>			1	0%	
	Mandarin early season total						
	Mandarin mid	Afourer			36	0%	
		Daisy			2	0%	
		Dekopon			5	0%	
		Ellendale			5	0%	
	Mandarin mid season total						
	Mandarin late	Murcott			3	0%	
	Mandarin total						
Navel		<i>unspecified navel</i>			196	2%	
	Navel early season	<i>unspecified early navel</i>			5	0%	
		Atwood			29	0%	
		Fisher			5	0%	
		Fukumoto			8	0%	
		Leng			66	1%	
		M7 Navel			6	0%	
		Navelina(Italian,Spanish)			189	2%	
		Nucellar Leng			4	0%	
		Pasin			18	0%	
		Rosey Red			2	0%	
		Ryan			10	0%	
		Thomson			0	0%	
		Winter Navel			1	0%	
	Navel early season total						
	Navel mid season	Cara Cara (Red Navel)			87	1%	
		Palmer			3	0%	
		Washington			1,205	14%	
	Navel mid season total						

Riverina citrus varieties continued

CATEGORY	VARIETY	2011 HECTARES	CATEGORY		
			Bearing	Non- bearing	Total
	Navel	<i>unspecified late navel</i>			213 2%
	late season	Autumn Gold			3 0%
		Barnfield			72 1%
		Chislett			117 1%
		Clark (Doug Clarke)			23 0%
		Late Lane			857 10%
		Powell			73 1%
		Summer Gold (Marrows)			2 0%
		Toc			12 0%
		Wiffen			3 0%
		Navel late season total			
	Navel total				
Orange	Blood	<i>unspecified</i>			6 0%
misc.	Orange	Arnold (Moro)			29 0%
		Maltese			0 0%
		Ruby			1 0%
		Tarocco			3 0%
	Sweet	Acidless (Non Acid)			0 0%
	Orange	Common Orange			1 0%
		Hamlin			128 1%
		Lima acidless			3 0%
		Parson Brown			27 0%
		Pera (Bianchi, Limeria)			19 0%
		Pineapple			35 0%
		Salustiana			174 2%
		Seleta (Siletta)			0 0%
	Sour	Seville			3 0%
Tangelo	Tangelo	<i>unspecified Tangelo</i>			14 0%
		Minneola			6 0%
Valencia	Valencia	Dwarf			7 0%
		Pecta			2 0%
		Valencia			4,105 47%
	Seedless	Delta			28 0%
	Valencia	McMahon			13 0%
		Midknight			13 0%
		Valencia Seedless			66 1%
Total					8,800 100%

1.2.3 Riverina change since 2003

CATEGORY		VARIETY	2011 Hectare	Change since 2003	2011 Trees	Change since 2003	
Citrus		<i>not surveyed</i>	567	+154	216,132	+27,441	
Grapefruit	white	<i>unspecified grapefruit</i>	78	-12	30,656	-4,848	
	flesh	Marsh	15	0	5,304	-155	
		Oroblanco	0	-2	0	-487	
		pink & red	Flame	0	0	652	+652
	flesh	Rio Red (Rio Star)	1	0	234	0	
		Ruby(Red,Pink),Redblush	6	0	3,560	+2,636	
		Star Ruby	19	+10	7,768	+5,023	
		Thompson (Eagle)	0	-1	0	-200	
Lemon	<i>unspecified lemon</i>	56	-24	23,235	-8,060		
	Eureka	36	+23	14,555	+10,035		
	Lisbon	2	-1	807	-325		
	Meyer	0	-2	0	-567		
Lime	<i>unspecified lime</i>	1	0	504	+160		
	Tahitian	1	+1	1,008	+709		
Mandarin	Mandarin	<i>unspecified mandarin</i>	42	+28	15,291	+9,947	
		Tangerine	1	0	407	0	
	Mandarin early	Imperial	40	+7	18,247	+5,960	
		Nules Clementine	4	0	1,482	0	
		Okitsu Wase Satsuma	0	0	246	0	
		<i>Satsuma unspecified</i>	1	+1	119	0	
		Mandarin early season total					
	Mandarin mid	Afourer	36	+36	26,145	+26,145	
		Daisy	2	-1	529	-256	
		Dekopon	5	+5	2,700	+2,700	
		Ellendale	5	-9	1,833	-3,035	
	Mandarin mid season total						
	Mandarin late	Murcott	3	-12	1,287	-4,598	
	Mandarin total						
	Navel	Navel	<i>unspecified navel</i>	196	-51	84,121	-23,191
		Navel early	<i>unspecified early navel</i>	5	+1	2,469	+427
			Atwood	29	+18	15,755	+10,111
Fisher			5	0	2,138	0	
Fukumoto			8	+7	6,745	+5,698	
Leng			66	-22	28,061	-12,810	
M7 Navel			6	+6	3,590	+3,590	
Navelina(Italian,Spanish)			189	0	81,655	-2,058	
Nucellar Leng			4	+4	3,372	+3,372	
Pasin			18	+1	10,498	+806	
Rosey Red			2	0	1,054	0	
Ryan			10	0	4,458	0	
Thomson			0	-2	200	-779	
Winter Navel			1	0	275	-12	
Navel early season total							
Navel mid		Cara Cara	87	+43	40,872	+20,880	
		Palmer	3	+1	2,622	+841	
		Washington	1,205	-40	469,528	-12,115	
Navel mid season total							

Riverina change since 2003 *continued*

CATEGORY		VARIETY	2011 Hectare	Change since 2003	2011 Trees	Change since 2003
Navel late		<i>unspecified late navel</i>	213	+20	85,354	+14,535
		Autumn Gold (Pollock Late)	3	0	1,329	0
		Barnfield	72	+24	26,951	+11,009
		Chislett	117	+45	47,657	+16,622
		Clark (Doug Clarke)	23	0	5,695	+133
		Late Lane	857	+12	355,473	+9,431
		Powell	73	+38	32,859	+18,898
		Summer Gold (Marrows)	2	-1	831	-156
		Toc	0	-12	0	-4,289
		Wiffen	3	0	1,241	0
Navel late season total						
Navel total						
Orange misc.	Blood	<i>unspecified</i>	6	-3	2,679	-1,106
	Orange	Arnold (Moro)	29	+29	24,243	+24,135
		Maltese	0	0	0	-155
		Ruby	1	0	498	0
		Tarocco	3	+3	1,030	+1,030
	Sweet	Acidless (Non Acid)	0	0	0	0
	Orange	Common Orange	1	-4	418	-2,947
		Hamlin	128	+61	79,854	+36,655
		Lima acidless	3	0	3,175	+1,450
		Parson Brown	27	+18	18,537	+9,884
		Pera (Bianchi, Limeria)	19	0	5,994	0
		Pineapple	35	+34	16,956	+16,251
		Salustiana	174	+138	106,237	+73,672
		Seleta (Siletta)	0	-2	0	-1,069
	Sour	Seville	3	-3	1,080	-1,384
	Tangelo	<i>unspecified Tangelo</i>	14	0	5,028	0
		Minneola	6	0	2,183	0
	Valencia	Dwarf	7	0	8,587	0
		Pecta	2	0	544	0
		Valencia	4,105	-126	1,573,117	-33,058
	Seedless	Delta	28	+24	13,164	+10,446
	Valencia	McMahon	13	+10	7,063	+4,939
		Midnight	13	0	5,263	+521
		Valencia Seedless	66	+6	22,329	+2,622
Total			8,800	+483	3,586,241	+272,464

1.3 Murray Valley

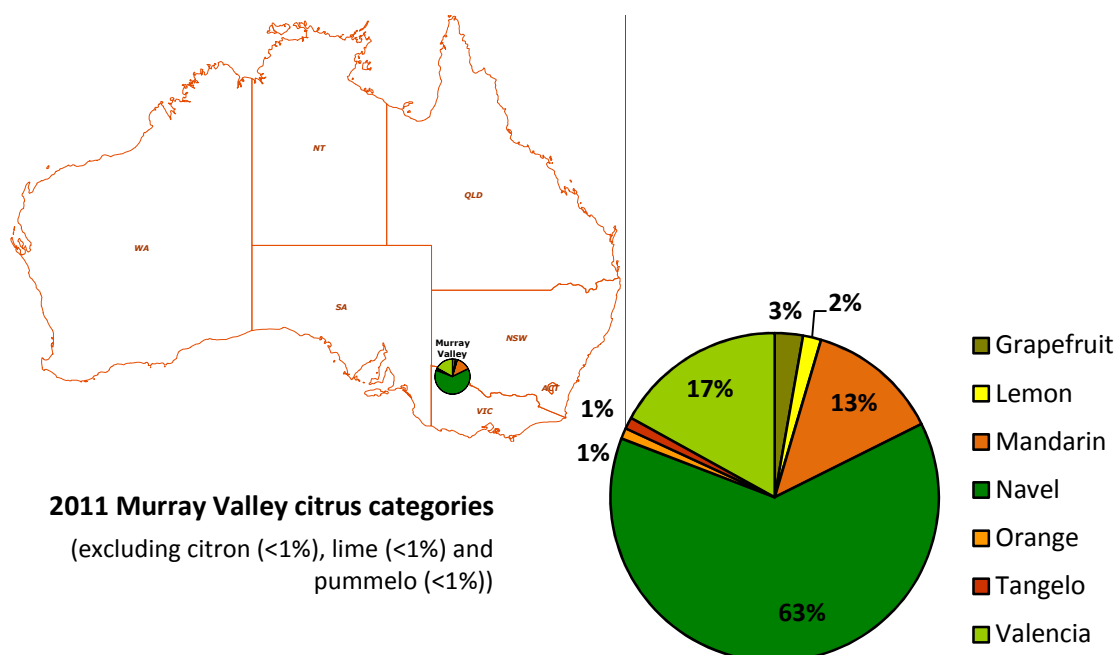
Murray Valley citrus growers were surveyed by the Murray Valley Citrus Board (MVCB) in October 2010. Property survey maps were prepared by SunRISE 21 using February 2009 aerial photography as the map base. Survey returns were collected by the MVCB, and updating of the citrus mapping and plantings database was undertaken by the MVCB and SunRISE 21.

1.3.1 Murray Valley citrus

In summary for Murray Valley citrus:

- In 2011; 6,580 hectares of citrus (3,095,349 trees) across 477 citrus properties were mapped and 263 hectares were new plantings since 2008. New plantings are predominantly navels and Imperial mandarin
- The area of citrus declined from 7,128 hectares in 2003 to 6,569 hectares in 2008 (-8%), then increased slightly to 6,580 hectares in 2011
- The number of citrus trees declined from 3,144,407 in 2003 to 3,083,834 in 2008, then increased to 3,095,349 trees in 2011
- Murray Valley predominantly grows Late Lane navels, Valencia oranges, Washington navels, Imperial mandarins and Leng navels
- Murray Valley citrus is predominantly drip irrigated and grown on a citrange rootstock
- The number of citrus growers continues to decline with 622 growers in 2003, 522 in 2008 and 477 growers in 2011.
- The average citrus area per property increased from 11.5 hectares in 2003 to 12.6 hectares in 2008 and 13.8 hectares in 2011

Figure 3 – Murray Valley citrus

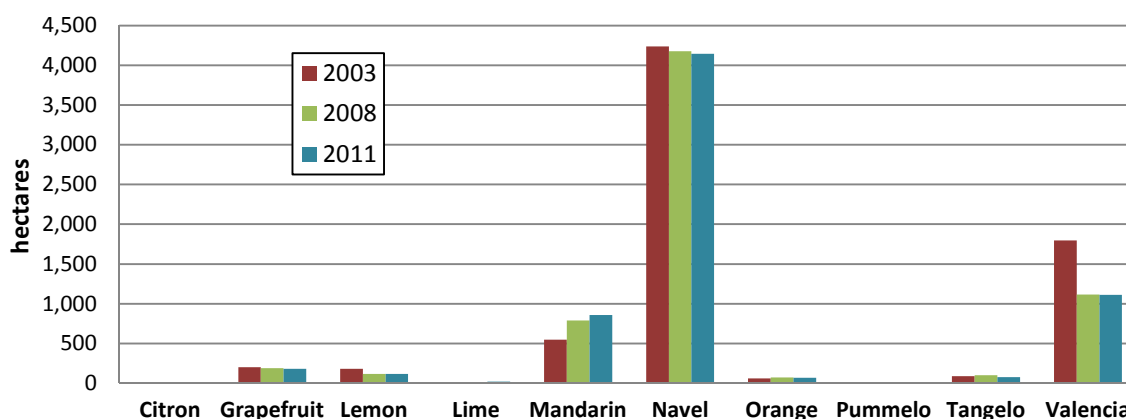


Murray Valley citrus 2003 to 2011

The area of citrus in the Murray Valley declined from 7,128 hectares in 2003 to 6,569 hectares in 2008 then increased slightly to 6,580 hectares in 2011. The overall change from 2003 to 2011 is an 8% decline in area planted (-548 hectares) and a 2% decrease in tree numbers (49,058 trees) as shown in Table 10.

Table 10 – Murray Valley citrus 2003 to 2011

Category	2003		2008		2011		Change 2003-2011	
	ha	trees	ha	trees	ha	trees	ha	trees
Citron	0	0	<1	49	<1	49	<1	+49
Cumquat	-	-	-	-	-	-	-	-
Grapefruit	202	99,319	188	87,058	184	84,624	-19	-14,695
Lemon	180	76,222	119	48,527	117	49,652	-63	-26,570
Lime	10	4,882	6	2,874	21	9,838	+11	+4,956
Mandarin	547	255,925	790	449,674	858	490,242	+310	+234,3
Navel	4,238	1,919,066	4,177	1,945,506	4,144	1,926,456	-95	+7,390
Orange	62	29,588	72	38,037	69	37,630	+7	+8,043
Pummelo	1	493	1	506	1	511	0	+17
Tangelo	89	44,640	101	51,383	75	38,884	-14	-5,756
Valencia	1,797	714,273	1,115	460,220	1,113	457,463	-684	-
Total	7,128	3,144,407	6,569	3,083,834	6,580	3,095,349	-548 -8%	-49,058 -2%
Average	441 trees/ha		469 trees/ha		470 trees/ha			



Note: 3% of citrus categories are unknown. A linear extrapolation was applied to account for the 3%
Tree numbers are estimates from a range of sources; grower input, calculations & counts from imagery

Dominant variety

The dominant Murray Valley citrus variety changed from Valencia in 2003 to Late Lane navel in 2008 and 2011.

Dominant variety			
	2003	2008	2011
1	Valencia	Late Lane	Late Lane
2	Late Lane	Valencia	Valencia
3	Washington	Washington	Washington
4	Leng	Leng	Imperial
5	Navelina	Imperial	Leng

Murray Valley citrus rootstocks, irrigation and properties

Murray Valley citrus is predominantly drip irrigated and grown on a Citrange rootstock as shown in Table 11.

Table 11 – Murray Valley trees per hectare (bearing and non-bearing), dominant rootstock and irrigation type

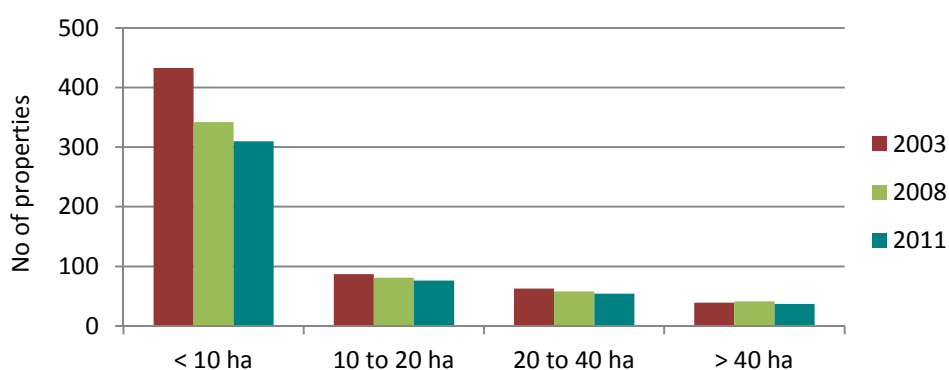
	2011 trees/ha		2011 Dominant rootstock	Dominant irrigation		
	Non-bearing	bearing		2003	2008	2011
Citron	0	1,693	Citrange		Low level	Low level
Grapefruit	0	0	Citrange	Overhead	Overhead	Low level
Lemon	538	457	Citrange	Overhead	Overhead	Drip
Lime	499	411	Citrange	Drip	Drip	Low level
Mandarin	461	478	Citrange	Overhead	Drip	Drip
Navel	676	527	Citrange	Overhead	Drip	Drip
Orange	529	456	Citrange	Low level	Drip	Drip
Pummelo	652	523	Sweet Orange	Overhead	Overhead	Overhead
Tangelo	0	368	Citrange	Low level	Low level	Drip
Valencia	976	510	Citrange	Overhead	Overhead	Overhead
Total	500	405	Citrange	Overhead	Drip	Drip

Citrus properties

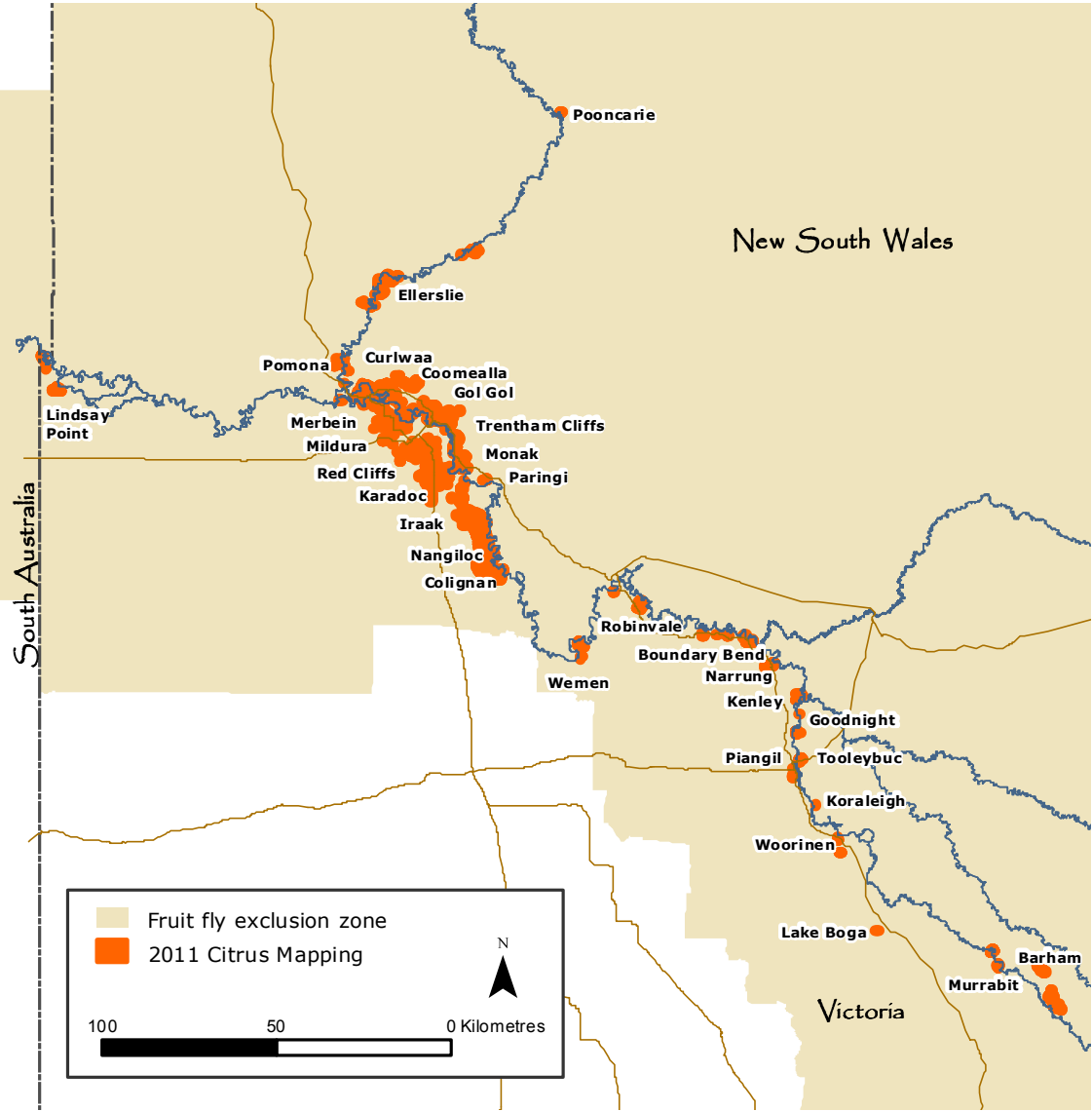
While the number of citrus growers declined by 145 between 2003 and 2011; the average property size increased from 11.5 to 13.8 hectares of citrus as shown in Table 12.

Table 12 – Murray Valley citrus properties

Property size (citrus area)	Number of properties			Change 2003 to 2011	
	2003	2008	2011	properties	% of 2003
< 10 ha	433	342	310	-123	-20%
10 to 20 ha	87	81	76	-11	-2%
20 to 40 ha	63	58	54	-9	-1%
> 40 ha	39	41	37	-2	0%
Total properties	622	522	477	-145	-23%
Average property size (ha of citrus)	11.5	12.6	13.8		



Map 2 – Murray Valley citrus map



1.3.2 Murray Valley 2011 citrus varieties

CATEGORY		VARIETY	2011 HECTARES			
			Bearing	Non Bearing	Total	
Citrus		<i>not surveyed</i>	111	116	227	3%
Citron		Buddha's Hand	<1	0	<1	0%
Grapefruit	Grapefruit white flesh	<i>unspecified</i>	35	0	35	1%
		Marsh	62	0	62	1%
		Oroblanco	1	0	1	0%
	Grapefruit pink & red flesh	Flame	<1	0	<1	0%
		Rio Red	2	1	4	0%
		Ruby, Redblush	7	1	8	0%
		Star Ruby	23	6	29	0%
		Thompson	37	0	37	4%
	Lemon	<i>unspecified</i>	34	3	37	1%
		Eureka	20	0	20	0%
		Fino	<1	0	<1	0%
		Francovielo	1	0	1	0%
		Lisbon	39	12	52	1%
		Meyer	1	0	1	0%
		Verna	1	0	1	0%
		Yen Ben	<1	0	<1	0%
Lime		<i>unspecified</i>	1	14	15	0%
		Finger	1	0	1	0%
		Tahitian	2	3	5	0%
Mandarin		<i>unspecified mandarin</i>	3	3	6	0%
	Mandarin early season	Amigo	2	0	2	0%
		Caffin Clementine	0	<1	<1	0%
		Clementine	1	0	1	0%
		Fallglo	<1	0	<1	0%
		Feutrell	1	0	1	0%
		Fremont	0	1	1	0%
		Imperial	332	94	426	6%
		Miho Wase Satsuma	1	0	1	0%
		Okitsu Wase Satsuma	1	0	1	0%
		Mandarin early season total	337	95	432	7%
	Mandarin mid season	Afourer	167	119	286	4%
		Avana (Aperino,Tardivo)	1	0	1	0%
		Daisy	17	8	25	0%
		Ellendale	33	0	33	0%
		Hickson	2	0	2	0%
		Mandarin mid season total	219	127	346	5%
	Mandarin late season	Emperor	1	0	1	0%
		Kara (Carra)	1	0	1	0%
		Murcott	35	0	35	1%
		Topaz, Ortanique	4	3	7	0%
		Mandarin late season total	40	3	43	1%
	Mandarin total		599	229	828	13%

Murray Valley citrus varieties *continued*

CATEGORY	VARIETY	2011 HECTARES			
		Bearing	Non Bearing	Total	
Navel	<i>unspecified</i>	44	0	44	1%
	Navel	12	19	31	0%
early season	Biggs Leng	2	0	2	0%
	Early Bird	<1	0	<1	0%
	Fisher	18	7	25	0%
	Fuko Mozonau	5	0	5	0%
	Fukumoto	3	1	4	0%
	Golden Nugget	1	0	1	0%
	Hammet	1	0	1	0%
	Leng	398	17	415	6%
	Lloyd Leng	1	0	1	0%
	M7	2	52	53	1%
	Navelina	334	1	335	5%
	Newhall	7	0	7	0%
	Nucellar Leng	22	0	22	0%
	Pasin	3	3	6	0%
	Riverside	1	1	2	0%
	Ryan	57	0	57	1%
	Thomson	16	2	18	0%
	Whitely	6	0	6	0%
Navel early season total		888	103	992	15%
Navel mid season	Bellamy	<1	0	<1	0%
	Cara Cara	19	24	43	1%
	Cellaline	<1	0	<1	0%
	Follett	<1	0	<1	0%
	Hockney	2	0	2	0%
	Langdon	10	0	10	0%
	Navelate	1	0	1	0%
	Palmer	<1	0	<1	0%
	Salisbury	2	0	2	0%
	Washington	627	39	665	10%
Navel mid season total		662	63	724	11%
Navel late season	<i>unspecified</i>	20	0	20	0%
	Autumn Gold	71	4	75	1%
	Barnfield	187	6	193	3%
	Chislett	282	41	323	5%
	Christensen	3	0	3	0%
	Christmas	<1	0	<1	0%
	Clark	8	0	8	0%
	Edwards	2	0	2	0%
	Honey Gold	2	0	2	0%
	Hutton	1	0	1	0%
	Late Lane	1,257	92	1,350	21%
	Powell	106	1	107	2%
	Ravens Choice	5	0	5	0%
	Rohde	41	2	43	1%
	Scopelliti	6	0	6	0%
	Summer Gold	89	1	90	1%
	Taylor	1	0	1	0%
	Toomey	3	0	3	0%
	Wiffen	8	0	8	0%
Navel late season total		2,094	147	2,241	34%
Navel total		3,687	314	4,001	61%

Murray Valley citrus varieties *continued*

CATEGORY		VARIETY	2011 HECTARES			
			Bearing	Non Bearing	Total	
Orange misc.	Blood	unspecified	10	3	12	0%
	Orange	Arnold Blood	11	4	15	0%
		Maltese	0	0	0	0%
	Sweet	Common Orange	1	0	1	0%
		Hamlin	11	0	11	0%
		Parson Brown	2	0	2	0%
		Pera	0	0	0	0%
		Salustiana	1	2	4	0%
	Sour	Seville	21	0	21	0%
		Smooth Seville	1	0	1	0%
Pummelo	unspecified	1	0	1	0%	
Tangelo	unspecified	35	1	36	1%	
	Minneola	36	0	36	1%	
	Seminole	0	0	0	0%	
Valencia	Appleby	1	0	1	0%	
	Ben Yenda	0	0	0	0%	
	Berri	4	0	4	0%	
	Casey	8	0	8	0%	
	Keenan	0	2	2	0%	
	Newton	36	0	36	1%	
	Owen	0	0	0	0%	
	Smith	9	0	9	0%	
	Valencia	963	12	976	15%	
	Seedless	Delta	7	1	9	0%
	Valencia	McMahon	2	3	5	0%
		Midknight	0	4	4	0%
		Valencia Seedless	7	14	21	0%
		TOTAL		5,835	746	6,580

Note: Bearing trees were planted six or more years ago (i.e. planted in 2005 or earlier) or were reworked three or more years ago (i.e. reworked in 2008 or earlier).

1.3.3 Murray Valley change since 2003

CATEGORY		VARIETY	2011 Hectare	Change since 2003	2011 Trees	Change since 2003
Citrus		<i>not surveyed</i>	227	+177	125,193	+103,240
Citron		Buddha’s Hand	0	0	47	+47
Grapefruit	Grapefruit white flesh	<i>unspecified</i>	35	-23	15,791	-10,460
		Marsh	62	-31	27,426	-20,660
		Oroblanco	1	-4	756	-3,228
	Grapefruit pink & red flesh	Flame	0	0	231	0
		Rio Red	4	+3	1,669	+982
		Ruby, Redblush	8	0	3,302	0
		Star Ruby	29	+6	14,167	+3,686
		Thompson	37	+23	17,859	+11,293
		Lemon	<i>unspecified</i>	37	-23	16,587
	Eureka	20	-12	7,887	-7,849	
	Fino	0	-1	14	-340	
	Francovielo	1	0	541	0	
	Lisbon	52	-28	21,683	-9,825	
	Meyer	1	0	210	-31	
	Verna	1	-2	459	-693	
	Yen Ben	0	0	263	0	
Lime	<i>unspecified</i>	15	+14	6,597	+6,175	
	Blood	0	-4	0	-1,907	
	Desert	0	-1	0	-696	
	Finger	1	+1	442	+392	
	Kaffir	0	0	0	-50	
	Outback	0	-1	0	-583	
	Sunrise	0	-1	0	-397	
	Tahitian	5	+3	2,401	+1,658	
Mandarin	<i>unspecified</i>	6	+3	2,617	-119	
	Mandarin early season	Amigo	2	-3	926	-1,598
		Caffin Clementine	0	0	145	+145
		Clementine	1	-3	281	-1,294
		Fallglo	0	-3	289	-2,142
		Feutrell	1	0	139	0
		Fremont	1	+1	380	+380
		Imperial	426	+91	216,110	+64,314
		Miho Wase Satsuma	1	+1	450	+90
		Nova	0	0	0	-72
		Okitsu Wase Satsuma	1	-1	692	-68
		Satsuma <i>unspecified</i>	0	-1	0	-446
	Mandarin early season total		432	82	219,412	59,309
	Mandarin mid season	Afourer	286	+277	193,870	+ 186,908
		Avana	1	+1	430	+336
		Daisy	25	+11	14,672	+7,149
		Dancy	0	0	0	-32
		Ellendale	33	-48	14,470	-19,875
		Hickson	2	0	479	0
	Mandarin mid season total		346	241	223,921	174,487
	Mandarin late season	Emperor	1	-1	300	-412
		Kara	1	-1	700	-14
		Murcott	35	-40	19,716	-17,673
		Sunset	0	0	0	-100
		Topaz, Ortanique	7	+1	3,748	+798
Mandarin late season total		43	-42	24,464	-17,401	
Mandarin total			828	284	470,414	216,276

Murray Valley change since 2003 continued

CATEGORY		VARIETY	2011 Hectare	Change since 2003	2011 Trees	Change since 2003
Navel	Navel	<i>unspecified</i>	44	-1	25,505	-969
	Navel	Atwood	31	+23	17,752	+11,748
	early season	Biggs Leng	2	0	664	0
		Early Bird	0	0	98	+98
		Fisher	25	+24	12,178	+11,928
		Fuko Mozonau	5	+5	4,490	+4,490
		Fukumoto	4	-5	2,206	-2,436
		Golden Nugget	1	0	418	0
		Hammet	1	-1	600	-440
		Leng	415	-161	157,494	-61,563
		Lloyd Leng	1	-1	482	-288
		M7	53	+53	31,184	+31,184
		Navelina	335	-77	169,243	-40,370
		Newhall	7	-6	3,287	-2,909
		Nucellar Leng	22	-1	10,677	-469
		Pasin	6	+3	2,812	+1,388
		Riverside	2	+1	653	+314
		Ryan	57	+10	24,124	+4,844
		Thomson	18	-23	7,541	-10,552
		Whitely	6	-1	3,212	-440
Navel early Total		992	-156	449,115	-53,474	
Navel mid season	Bellamy	0	0	138	-54	
	Cara Cara	43	+43	24,248	+23,548	
	Cellaline	0	0	40	0	
	Follett	0	0	120	0	
	Hockney	2	+1	1,060	+560	
	Langdon	10	+2	3,895	+696	
	Navelate	1	-3	330	-1,167	
	Palmer	0	0	83	0	
	Salisbury	2	0	648	0	
	Washington	665	-128	286,437	-55,592	
Navel mid Total		724	-85	316,999	-32,009	
Navel late season	<i>unspecified</i>	20	-1	9,337	-635	
	Autumn Gold	75	+1	42,078	+1,739	
	Barnfield	193	-11	88,169	-5,616	
	Chislett	323	+93	170,507	+52,742	
	Christensen	3	0	1,356	0	
	Christmas	0	0	200	0	
	Clark	8	-1	4,714	+356	
	Edwards	2	0	1,036	0	
	Honey Gold	2	0	1,329	0	
	Hutton	1	0	341	0	
	Late Lane	1,350	+5	610,222	+8,053	
	Pillar	0	0	0	-147	
	Powell	107	-14	46,305	-7,236	
	Ravens Choice	5	+3	1,601	+729	
	Rohde	43	-3	19,366	-1,069	
	Scopelliti	6	-1	2,976	-866	
	Summer Gold	90	-35	52,026	-18,438	
	Taylor	1	0	356	0	
	Toomey	3	0	1,423	0	
	Wiffen	8	+1	3,578	-127	
Navel late season total		2,241	35	1,056,921	29,324	
Navel total		4,001	-208	1,848,540	-57,128	

Murray Valley change since 2003 continued

CATEGORY		VARIETY	2011 Hectare	Change since 2003	2011 Trees	Change since 2003
Orange misc.	Blood	unspecified	12	0	6,620	+721
	Orange	Arnold Blood	15	+5	9,403	+3,762
		Maltese	0	0	31	+31
		Sweet	Common Orange	1	-1	363
		Hamlin	11	+1	6,572	+ 144
		Parson Brown	2	+2	1,224	+1,224
		Pera	0	0	65	0
		Salustiana	4	+3	3,443	+3,160
	Sour	Seville	21	-6	7,429	-2,137
		Smooth Seville	1	0	959	0
Pummelo	unspecified	1	0	490	0	
Tangelo	unspecified	36	+2	16,946	+1,785	
	Minneola	36	-18	20,334	-8,695	
	Seminole	0	0	31	-107	
Valencia	Appleby	1	-2	463	-330	
	Ben Yenda	0	0	422	0	
	Berri	4	+2	3,438	+1,730	
	Casey	8	-13	3,082	-5,580	
	Keenan	2	0	1,111	+257	
	Newton	36	-40	14,858	-21,619	
	Owen	0	0	53	0	
	Smith	9	-2	5,155	-561	
	Valencia	976	-682	391,099	-257,750	
	Seedless	Delta	9	+2	4,921	+1,446
	Valencia	McMahon	5	+4	2,308	+1,906
		Midknight	4	+4	2,280	+1,947
		Valencia Seedless	21	+17	9,772	+8,228
	TOTAL			6,580	-548	3,095,349

1.4 Riverland

South Australia 2011 citrus mapping and statistics were unavailable for incorporation in this report. The 2003 and 2008 information presented in this section is reproduced from the 2008 NPD report.

1.4.1 Riverland citrus

In summary for Riverland citrus:

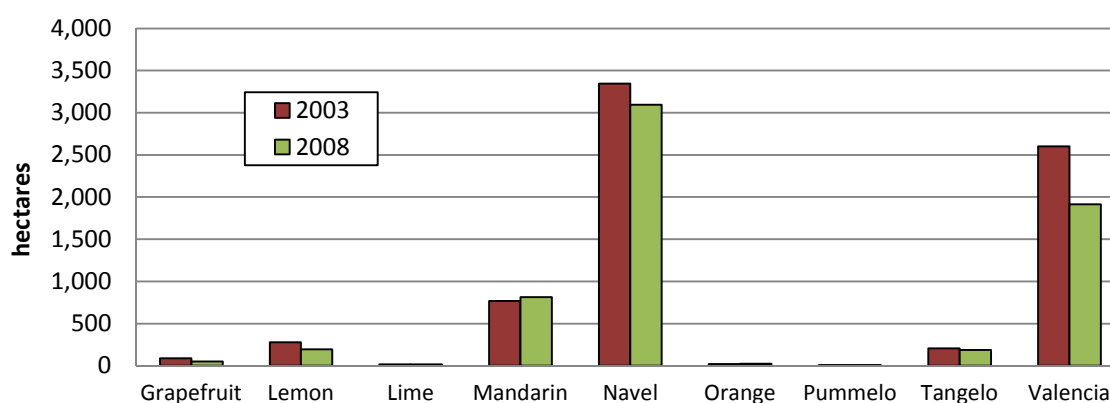
- In 2008; 6,303 hectares of citrus (2,746,859 trees) across 557 citrus properties were mapped
- Riverland predominantly grows navel oranges; the dominant variety in 2008 being Washington
- The area of citrus declined from 7,327 hectares in 2003 to 6,303 hectares in 2008 (a 14% decline)
- The number of citrus trees declined from 2,917,354 in 2003 to 2,746,859 in 2008 (a 6% decline)
- The number of citrus growers declined from 671 in 2003 to 557 in 2008 (a 17% decline); however the average citrus area per property increased from 10.9 hectares in 2003 to 11.3 hectares in 2008
- Riverland citrus is predominantly on a Citrange rootstock and irrigated with low level sprinklers

Riverland citrus 2003 to 2011

The area of citrus in the Riverland declined from 7,327 hectares in 2003 to 6,303 hectares in 2008. The overall change from 2003 to 2011 is unknown as 2011 figures are unavailable.

Table 13 – Riverland citrus 2003 to 2008

Category	2003		2008		2011		Change 2003-2011	
	ha	trees	ha	trees	ha	trees	ha	trees
Grapefruit	87	35,225	52	24,086				
Lemon	278	100,466	196	75,971				
Lime	18	6,608	16	5,233				
Mandarin	770	393,454	815	455,625				
Navel	3,347	1,375,758	3,095	1,378,294				
Orange	20	12,402	23	18,033				
Pummelo	0	120	2	889				
Tangelo	206	107,416	188	100,238				
Valencia	2,601	885,905	1,916	688,490				
Total	7,327	2,917,354	6,303	2,746,859			%	%
Average	398 trees/ha		436 trees/ha		trees/ha			



Note: 7% of citrus categories were unknown in 2008. A linear extrapolation was applied to account for the 7%.

Tree numbers are estimates from a range of sources; grower input, calculations & counts from imagery.

Dominant variety

There was no change in the order of dominant citrus varieties in the Riverland between 2003 and 2008.

Dominant variety			
	2003	2008	2011
1	Valencia	Valencia	
2	Washington	Washington	
3	Late Lane	Late Lane	
4	Navelina	Navelina	
5	Imperial	Imperial	

Riverland citrus rootstocks, irrigation and properties

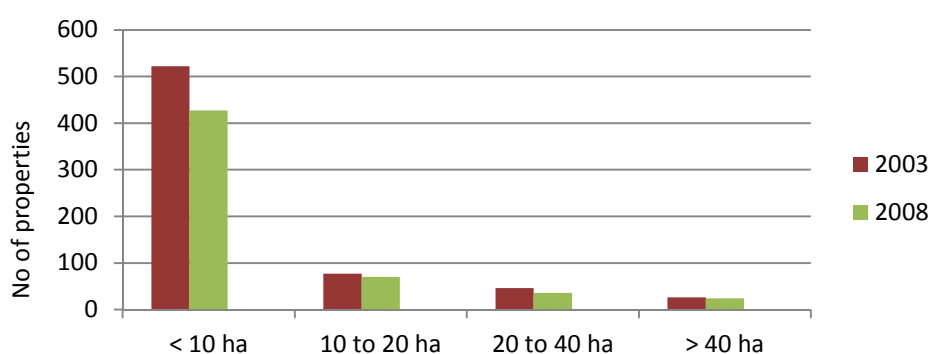
Table 14 – Riverland dominant rootstock and irrigation type

	2011 Trees/ha		Dominant rootstock 2008	Dominant irrigation		
	Non- bearing	bearing		2003	2008	2011
Grapefruit			Citrango	Low level	Low level	
Lemon			Citrango	Low level	Low level	
Lime			Citrango	Low level	Low level	
Mandarin			Citrango	Low level	Drip	
Navel			Citrango	Low level	Low level	
Orange			Citrango	Low level	Drip	
Pummelo			Citrango	Micro Sprinkler	Low level	
Tangelo			Citrango	Drip	Drip	
Valencia			Rough Lemon	Low level	Low level	
Total			Citrango	Low level	Low level	

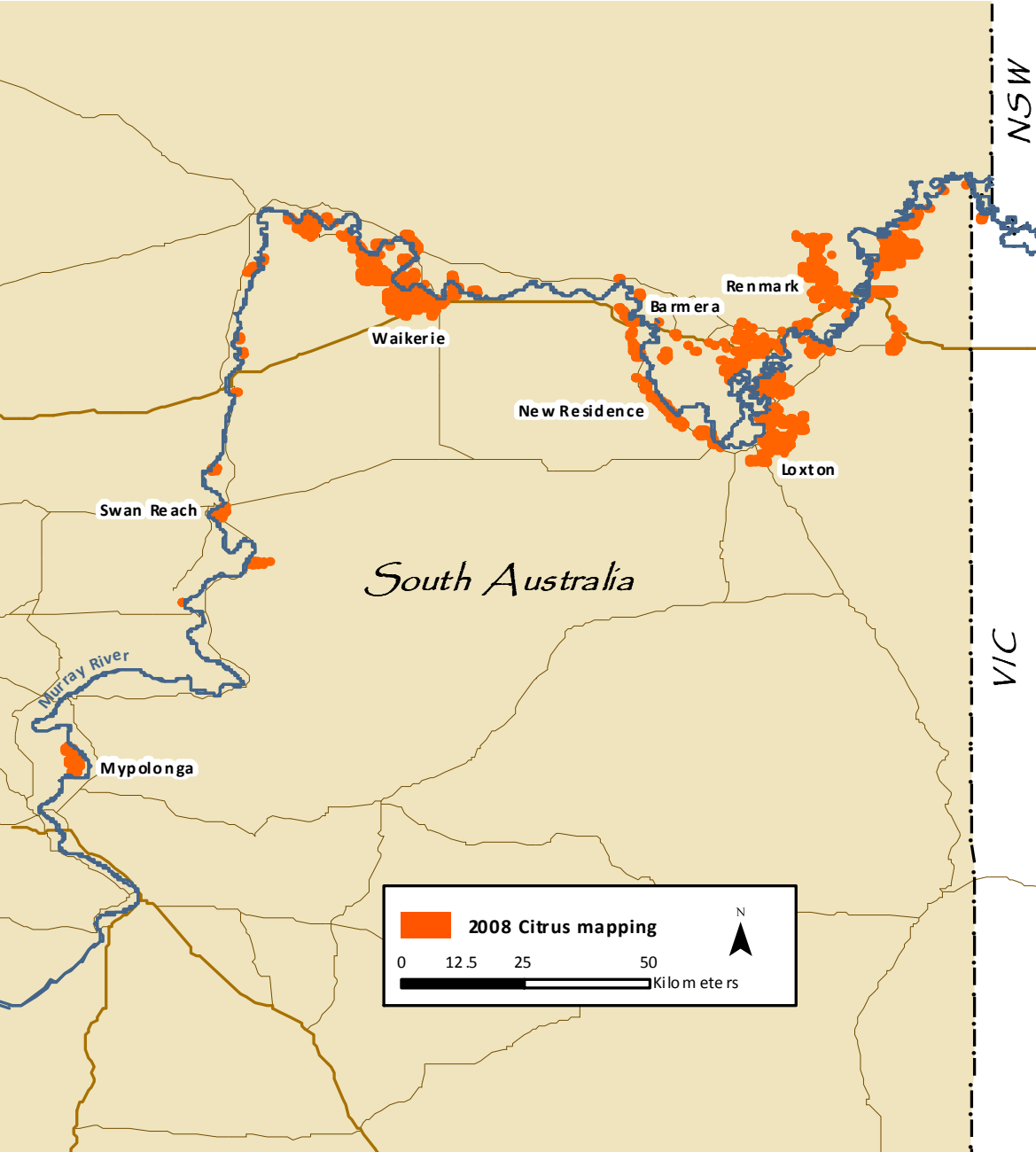
Riverland citrus properties

Table 15 – Riverland citrus properties

Property size (citrus area)	Number of properties			Change 2003 to 2011	
	2003	2008	2011	properties	% of 2003
< 10 ha	522	427			%
10 to 20 ha	77	70			%
20 to 40 ha	46	36			%
> 40 ha	26	24			%
Total properties	671	557			%
Average property size (ha of citrus)	10.9	11.3			



Map 3 – Riverland citrus map



1.4.2 Riverland 2008 citrus varieties

CATEGORY		VARIETY	2008 HECTARES			
			Bearing*	Non-Bearing	Total	
Citrus		<i>not surveyed</i>	232	231	463	7%
Grapefruit	Grapefruit	Grapefruit	9	0	9	0%
		Marsh	19	1	20	0%
		Oroblanco	0	0	0	0%
		Thompson	0	0	0	0%
	Grapefruit-Red	Flame	0	0	0	0%
		Ray Ruby	0	0	0	0%
		Rio Red	4	0	4	0%
		Ruby	0	0	0	0%
		Ruby Red	2	0	2	0%
		Star Ruby	13	1	13	0%
Lemon		Eureka	74	11	85	1%
		Fino	4	0	4	0%
		Lambert	0	0	0	0%
		Lemonade	2	0	2	0%
		Lisbon	78	7	85	1%
		Verna	6	0	6	0%
		Villa franca	1	0	1	0%
Lime		Blood Lime	0	0	0	0%
		Outback	1	0	1	0%
		Sunrise	0	0	0	0%
		Tahitian	11	4	14	0%
Mandarin		<i>unspecified</i>	1	0	1	0%
	Mandarin early season	Amigo	5	1	6	0%
		Clementine	32	12	44	1%
		Fallglo	10	1	12	0%
		Feutrell	0	0	0	0%
		Imperial	209	33	241	4%
		Miho Satsuma	0	2	2	0%
		Nova	0	16	16	0%
		Nules	49	2	51	1%
		Okitsu	5	0	5	0%
		Satsuma	20	0	20	0%
	Mandarin early season total					
	Mandarin mid season	Afourer	7	93	100	2%
		Avana Tardivo	0	7	7	0%
		Daisy	11	45	56	1%
		Dancy	1	0	1	0%
		Ellendale	69	0	69	1%
	Mandarin mid season total					
	Mandarin late season	Emperor	0	0	0	0%
		Hansen	0	0	0	0%
		Kara	5	0	5	0%
		Murcott	84	0	84	1%
		Ortanique	12	4	15	0%
		Topaz	5	16	21	0%
	Mandarin late season total					
Mandarin total						

Riverland 2008 citrus varieties *continued*

CATEGORY		VARIETY	2008 HECTARES			
			Bearing*	Non Bearing	Total	
Navel		unspecified	0	0	0	0%
	Navel	Cara Cara	11	10	21	0%
	early season	Fisher	1	0	1	0%
		Fukumoto	1	2	3	0%
		Fulwood	2	0	2	0%
		Italian Navelina	1	0	1	0%
		Leng	175	40	215	3%
		Navelina	294	68	362	6%
		Newhall	12	0	12	0%
		Pasin	3	0	3	0%
		Ryan	4	1	5	0%
		Spanish Navelina	1	0	1	0%
		Thomson	45	0	45	1%
		Winter Navel	5	0	5	0%
		Navel early season total				
	Navel	Atwood	1	1	2	0%
	mid season	Hockney	3	0	3	0%
		Navelate	1	0	1	0%
		Washington	1,021	94	1,114	18%
	Navel mid season total					
	Navel	Albanese	0	0	0	0%
	late season	Autumn Gold	9	0	9	0%
		Barnfield	110	17	126	2%
		Chislett	68	21	89	1%
		Hutton	26	12	38	1%
		Late Lane	459	154	613	10%
		Murray Gold	2	0	2	0%
		Navel-Late	18	6	24	0%
		Pollock	0	0	0	0%
		Powell	14	1	15	0%
		Rohde	0	1	1	0%
		Summer Gold	9	0	9	0%
		Summer Navel	55	21	76	1%
		Whiffen	3	1	4	0%
		Wilson	66	0	66	1%
		Navel late season total				
Navel total						
Orange	Orange	Hamlin	4	0	5	0%
		Parramatta	0	0	0	0%
		Pera	0	0	0	0%
		Poorman	0	0	0	0%
		Salustiana	0	6	6	0%
		Seville	1	0	1	0%
		Blood Orange	Arnold Blood	2	2	4
	Blood Orange		6	0	6	0%
	Pummelo					
		Pummelo	0	1	2	0%
Tangelo	Minneola	135	4	138	2%	
	Orlando	0	0	0	0%	
	Seminole	2	0	2	0%	
	Tangelo	22	11	33	1%	

Riverland 2008 citrus varieties *continued*

CATEGORY		VARIETY	2008 HECTARES			
			Bearing*	Non Bearing	Total	
Valencia	Valencia	Berri	1	0	1	0%
		Lord Howe	6	0	6	0%
		Valencia	1,727	15	1,743	28%
	Seedless	Delta	5	5	10	0%
	Valencia	Midnight	7	9	16	0%
		Valencia Seedless	1	0	1	0%
TOTAL			5,317	986	6,303	100%

*Bearing trees were planted six or more years ago (i.e. planted in 2005 or earlier) or were reworked three or more years ago (i.e. reworked in 2008 or earlier).

1.4.3 Riverland change 2003 to 2008

CATEGORY		VARIETY	2008 hectare	Change 2003-08	2008 trees	Change 2003-08
Citrus		<i>not surveyed</i>	463	+194	261,303	+150,732
Grapefruit	Grapefruit	<i>unspecified</i>	9	0	3,646	+13
		Marsh	20	-34	6,256	-11,852
		Oroblanco	0	0	66	-80
		Thompson	0	-2	0	-415
	Grapefruit red/pink flesh	Flame	0	0	55	0
		Ray Ruby	0	0	266	0
		Rio Red	4	0	2,447	+25
		Ruby	0	0	132	+75
		Ruby Red	2	0	750	-151
		Star Ruby	13	+1	8,177	+290
Lemon		Eureka	85	-44	33,914	-15,751
		Fino	4	0	1,388	-129
		Lambert	0	0	0	-140
		Lemonade	2	0	1,337	-78
		Lisbon	85	-40	29,504	-10,399
		Verna	6	-3	2,370	-1,552
		Villa Franca	1	0	231	+135
Lime		Blood Lime	0	0	44	0
		Outback	1	0	116	0
		Sunrise	0	-2	0	-806
		Tahitian	14	-1	4,575	-817
Mandarin		<i>unspecified</i>	1	0	191	+72
	Mandarin early season	Amigo	6	+1	2,541	+494
		Clementine	44	-9	28,190	-4,075
		Fallglo	12	-7	8,349	-7,230
		Feutrell	0	0	17	-44
		Imperial	241	-9	107,145	+5,047
		Miho Satsuma	2	0	1,650	0
		Nova	16	+15	10,320	+9,940
		Nules	51	-2	36,250	-1,071
		Okitsu	5	0	5,155	+320
		Satsuma	20	0	18,812	-38
	Mandarin early season total					
	Mandarin mid season	Afourer	100	+85	59,833	+47,947
		Avana Tardivo	7	+7	3,907	+3,907
		Daisy	56	+16	27,701	+10,581
		Dancy	1	-4	367	-972
		Ellendale	69	-52	30,245	-20,655
	Mandarin mid season total					
	Mandarin late season	Emperor	0	0	0	-5
		Hansen	0	-1	30	-418
		Kara	5	-13	1,341	-6,694
		Murcott	84	-26	50,563	-11,472
		Ortanique	15	+3	5,888	+1,199
		Topaz	21	+10	13,787	+6,907
	Mandarin late season total					
Mandarin total						

Riverland change 2003 to 2008 continued

CATEGORY		VARIETY	2008 hectare	Change 2003-08	2008 trees	Change 2003-08	
Navel		unspecified	0	-46	8	-16,888	
	Navel early season	Cara Cara	21	+9	8,712	+3,835	
		Fisher	1	-1	594	-550	
		Fukumoto	3	-3	1,745	-899	
		Fulwood	2	0	1,342	0	
		Italian Navelina	1	0	242	0	
		Leng	215	-30	86,654	-5,421	
		Navelina	362	-7	188,343	-4,754	
		Newhall	12	-2	9,462	-1,302	
		Pasin	3	-3	1,365	-1,662	
		Ryan	5	+2	1,923	+1,010	
		Spanish Navelina	1	0	261	0	
		Thomson	45	-22	16,564	-7,842	
		Winter Navel	5	0	1,442	-109	
		Navel early season total					
	Navel mid season	Atwood	2	+1	790	+630	
		Hockney	3	0	1,397	-72	
		Navelate	1	+1	213	+213	
	Navel mid season total						
	Navel late season	Albanese	0	0	96	0	
		Autumn Gold	9	0	4,691	-101	
		Barnfield	126	-1	57,372	-1,020	
		Chislett	89	+7	46,997	+4,106	
		Hutton	38	+9	17,923	+4,235	
		Late Lane	613	+32	273,606	+25,688	
		Murray Gold	2	0	1,167	-75	
		Navel-Late	24	-83	8,141	-30,002	
		Pollock	0	-1	0	-499	
		Powell	15	0	6,683	-57	
		Rohde	1	+1	486	+486	
		Summer Gold	9	0	6,144	-18	
		Summer Navel	76	+76	29,775	+29,775	
		Whiffen	4	+1	2,165	+233	
		Wilson	66	-12	29,137	-5,811	
		Navel late season total					
		Navel total					
Orange		Orange	Hamlin	5	0	3,640	+200
	Parramatta		0	-1	0	-333	
	Pera		0	0	110	+110	
	Poorman		0	0	50	0	
	Salustiana		6	+6	5,940	+5,940	
	Seville		1	-2	271	-813	
	Blood Orange	Arnold Blood	4	+1	1,516	+310	
		Blood Orange	6	-2	4,791	-1,028	
	Pummelo	Pummelo	2	+1	804	+689	
	Tangelo	Minneola	138	-19	68,726	-10,443	
Orlando		0	-3	104	-1,240		
Seminole		2	0	737	0		
Tangelo		33	-2	21,136	-959		
Valencia	Valencia	Berri	1	0	212	0	
		Lord Howe	6	+3	1,825	+1,024	
		Valencia	1,743	-738	608,941	-233,122	
	Seedless	Delta	10	+3	4,603	+1,800	
	Valencia	Midnight	16	+2	7,089	+965	
		Valencia Seedless	1	0	325	0	
TOTAL			6,303	-1,024	2,746,859	-170,495	

1.5 Queensland

Surveys of Queensland citrus growers were undertaken by SunRISE 21 in collaboration with Nathan Hancock, Citrus Australia. Survey maps were prepared by SunRISE 21 and mailed out to growers. The survey maps and 2011 data entry were based on 2009 SPOT satellite imagery (2.5m resolution) and 2010 Google Earth.

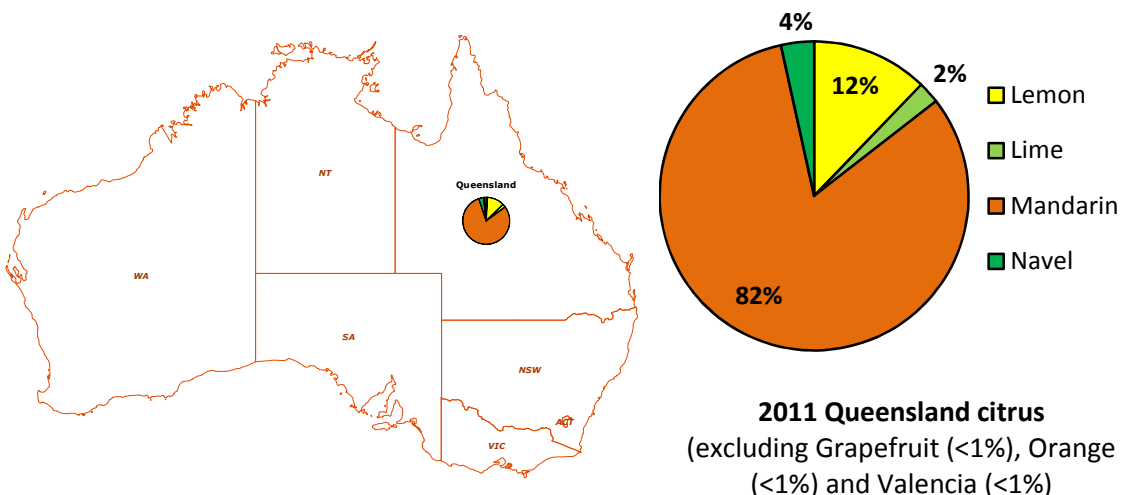
The main Queensland citrus growing regions are mapped, along with six new citrus properties at Mareeba and one at Elliott. There are mixed farms scattered along the Queensland coast that account for a significant proportion of Australia's lime production, but these have not been mapped for inclusion in the NPD.

1.5.1 Queensland citrus

In summary for Queensland citrus:

- In 2011; 3,592 hectares of citrus (1.48 million trees) across 84 citrus properties were mapped and 420 hectares were new plantings since 2008. New plantings are predominantly Murcott and Imperial mandarins
- The area of citrus declined from 4,645 hectares in 2003 to 3,850 hectares in 2008, then 3,592 hectares in 2011 (-27%)
- The number of citrus trees declined from 1.90 million in 2003 to 1.56 million in 2008, then to 1.48 million trees in 2011
- Gayndah and Mundubbera predominantly grow Imperial and Murcott mandarins, while the remainder of Queensland are predominantly lemon and lime.
- Queensland citrus is predominantly 'undertree' irrigation and grown on Troyer rootstock.
- The number of citrus growers declined from 104 growers in 2003 to 87 in 2008, then to 84 growers in 2011
- The average citrus area per property has also decreased from 44.7 hectares of citrus per property in 2003 to 44.3 hectares in 2008 and 42.7 hectares in 2011

Figure 4 – Queensland citrus

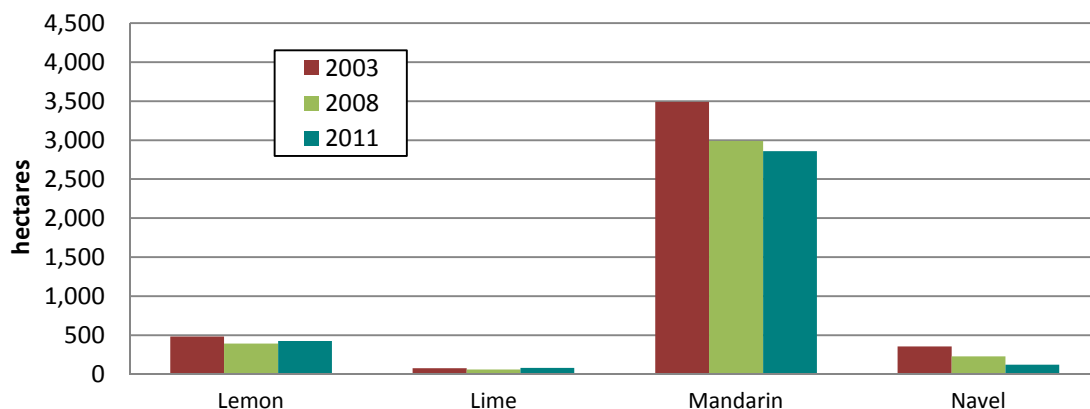


Queensland citrus 2003 to 2011

The area of citrus in Queensland declined from 4,645 hectares in 2003 to 3,850 hectares in 2008 then to 3,592 hectares in 2011. The overall change from 2003 to 2011 is a 23% decline in area planted (-1,054 hectares) and a 22% decrease in tree numbers (-421,301 trees) as shown in Table 16.

Table 16 – Queensland citrus 2003 to 2011

Category	2003		2008		2011		Change 2003-2011	
	ha	trees	ha	trees	ha	trees	ha	trees
Citron								
Cumquat	0	0	0	0	1	362	+1	+362
Grapefruit	78	27,884	62	22,198	31	10,770	-46	-17,114
Lemon	484	196,783	394	142,061	425	157,839	-59	-38,944
Lime	74	32,357	61	22,065	80	29,142	+5	-3,215
Mandarin	3,492	1,486,658	2,990	1,258,479	2,860	1,213,792	-632	-272,866
Navel	353	106,827	226	71,525	120	40,812	-234	-66,015
Orange	9	3,255	21	10,892	19	10,188	+10	+6,933
Pummelo	1	112	0	0	0	144	-1	+32
Tangelo	20	10,415	18	9,545	9	4,113	-11	-6,302
Valencia	135	39,604	79	24,308	47	15,431	-87	-24,173
Total	4,645	1,903,895	3,850	1,561,073	3,592	1,482,594	-1,054	-421,301
Average	410 trees/ha		405 trees/ha		413 trees/ha		-23%	



Note: 1% of citrus categories are unknown. A linear extrapolation was applied to account for the 1%
Tree numbers are estimates from a range of sources; grower input, calculations & counts from imagery

Dominant variety

Murcott mandarin has remained the dominant citrus variety in Queensland 2003 to 2011

Dominant variety			
	2003	2008	2011
1	Murcott	Murcott	Murcott
2	Imperial	Imperial	Imperial
3	Eureka	Eureka	Eureka
4	Washington	Hickson	Murcott LS
5	Hickson	Murcott LS	Hickson

Queensland citrus rootstocks, irrigation and properties

Queensland citrus is predominantly low level irrigation and grown on a Troyer rootstock as shown in Table 17.

Table 17 – Queensland trees per hectare (bearing and non bearing), dominant rootstock and irrigation type

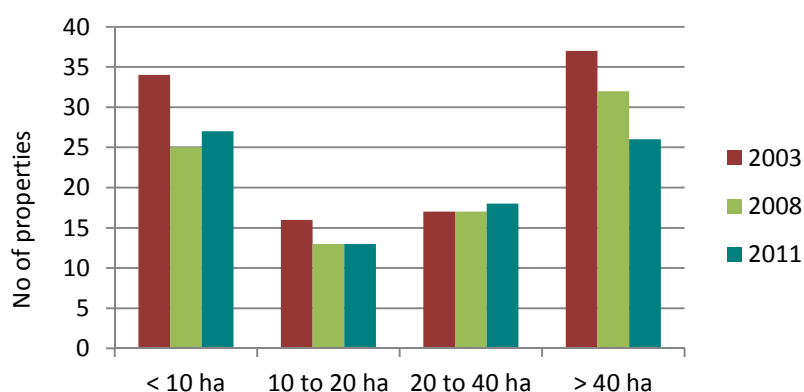
	2011 Trees/ha		Dominant rootstock 2011	Dominant irrigation		
	Non-bearing	bearing		2003	2008	2011
Grapefruit	360	0	Swingle	Low level	Low level	Low level
Lemon	311	346	Benton	Low level	Low level	Low level
Lime	386	365	Troyer	Low level	Low level	Low level
Mandarin	405	307	Troyer	Low level	Low level	Low level
Navel	441	416	Troyer	Low level	Low level	Low level
Orange	400	339	Troyer	Low level	Low level	Low level
Pummelo	628	427	Troyer	Low level	Low level	Low level
Tangelo	550	0	Troyer	Low level	Low level	Low level
Valencia	0	454	Troyer	Low level	Low level	Low level
Total	168	330	Troyer	Low level	Low level	Low level

Queensland citrus properties

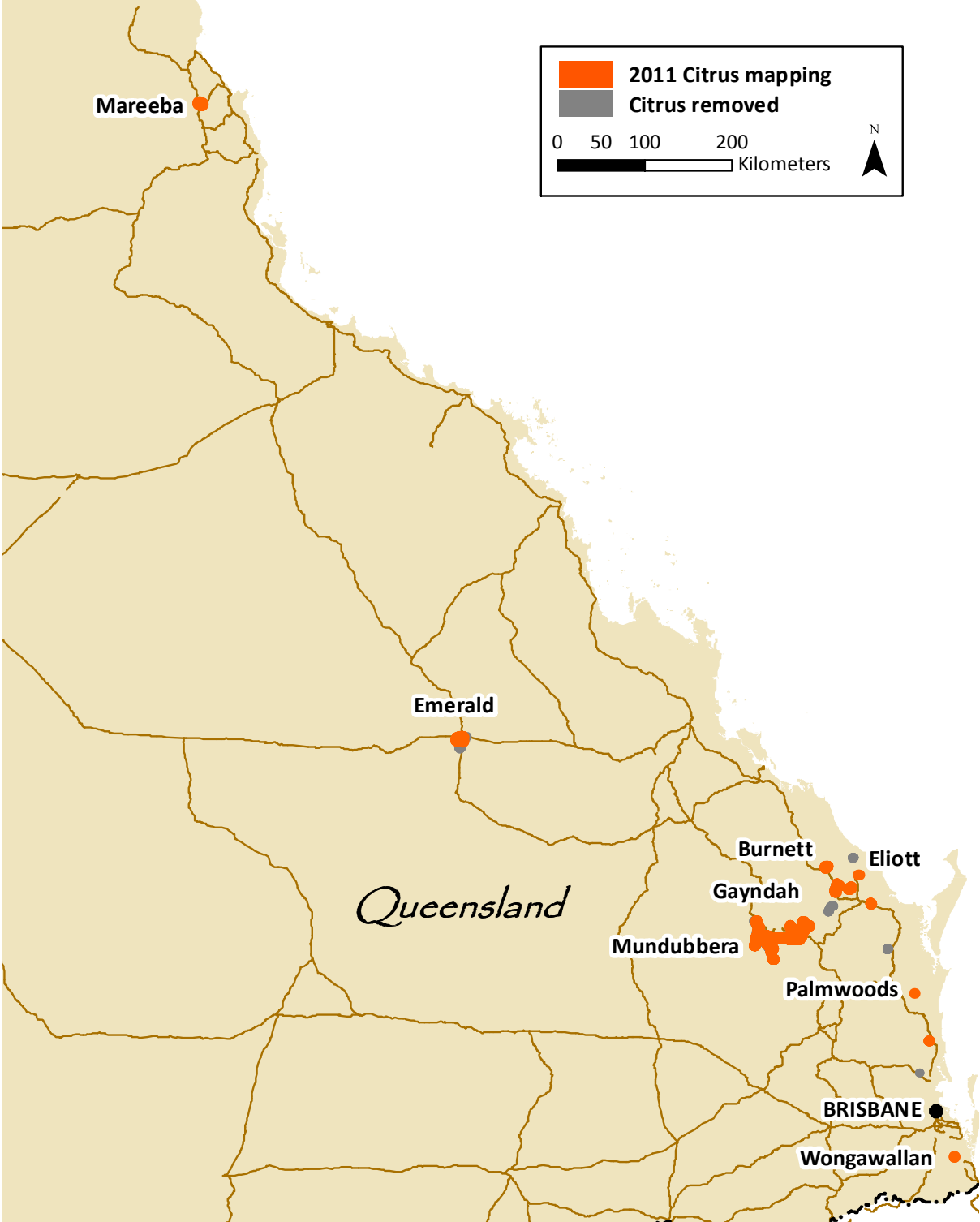
The number of citrus growers declined by 20 between 2003 and 2011, and the average property size also decreased from 44.7 hectares to 42.7 hectares of citrus per property as shown in Table 18.

Table 18 – Queensland citrus properties

Property size (citrus area)	Number of properties			Change 2003 to 2011	
	2003	2008	2011	properties	% of 2003
< 10 ha	34	25	27	-7	-7%
10 to 20 ha	16	13	13	-3	-3%
20 to 40 ha	17	17	18	+1	+1%
> 40 ha	37	32	26	-11	-11%
Total properties	104	87	84	-20	-19%
Average property size (ha of citrus)	44.7	44.3	42.7		



Map 4 – Queensland citrus map



1.5.2 Queensland 2011 citrus varieties

CATEGORY		VARIETY	2011 HECTARES			
			Bearing*	Non-Bearing	Total	
Citrus		<i>Not Surveyed</i>	9	16	25	1%
Cumquat		Cumquat	0	1	1	0%
Grapefruit	white flesh	Marsh	9	0	9	0%
	pink & red flesh	Rio Red	4	0	4	0%
		Ruby, Redblush	8	0	8	0%
		Star Ruby	9	1	10	0%
Lemon		<i>Unspecified</i>	2	16	18	1%
		Eureka	210	82	292	8%
		Eureka Seedless	3	43	46	1%
		Fino	3	0	3	0%
		Limonera	2	0	2	0%
		Lisbon	60	0	60	2%
Lime		<i>Unspecified</i>	3	20	23	1%
		Tahitian	28	28	56	2%
Mandarin	Mandarin early season	Fremont	28	0	28	1%
		Imperial	689	228	917	26%
		Nova	40	0	40	1%
		Mandarin early season total	758	265	1,023	28%
	Mandarin mid	Afourer	3	90	93	3%
		Avana	2	28	30	1%
		Daisy	18	8	26	1%
		Ellendale	24	0	24	1%
		Ellenor	7	0	7	0%
		Empress	44	3	46	1%
		Golden Nugget	0	4	4	0%
		Hickson	141	0	141	4%
		Monarch	3	0	3	0%
		Success	9	0	9	0%
		Sunburst	20	0	20	1%
		Taylor Lee	59	0	59	2%
		Mandarin mid season total	329	139	468	13%
	Mandarin late	Murcott	742	318	1,060	30%
		Murcott Honey	2	24	26	1%
		Murcott LS	14	248	262	7%
		Topaz	1	0	1	0%
		Mandarin late season total	758	591	1,349	38%
		Mandarin total	1,845	995	2,840	79%
Navel	Navel	Navelina	19	0	19	1%
	early season	Nucellar Leng	1	0	1	0%
	mid season	Washington	95	4	98	3%
	late season	Late Lane	0	0	0	0%
		Navel total	115	4	119	3%
Orange		Honey Ball	3	9	12	0%
		Joppa	5	0	5	0%
	Blood orange	Arnold Blood	1	1	2	0%
Pummelo		Pummelo	0	<1	<1	0%
Tangelo		Minneola	9	0	9	0%
Valencia	Valencia	Valencia	12	0	12	0%
		Valencia Late	23	0	23	1%
	Seedless Valencia	Midnight	11	1	12	0%
TOTAL			2,375	1,217	3,592	100%

*Bearing trees were planted six or more years ago (i.e. planted in 2005 or earlier) or were reworked three or more years ago (i.e. reworked in 2008 or earlier).

1.5.3 Queensland change since 2003

CATEGORY		VARIETY	2011 Hectare	Change since 2003	2011 Trees	Change since 2003
Citrus		<i>not surveyed</i>	25	+7	9,735	+3,532
Cumquat		Cumquat	1	+1	360	+360
Grapefruit	white flesh	Marsh	9	-26	3,461	-8,511
		Oroblanco	0	-1	0	-288
	pink & red flesh	Henderson	0	0	0	-63
		Rio Red	4	-4	1,560	-1,328
		Ruby, red blush	8	-4	2,157	-2,177
		Star Ruby	10	-11	3,521	-4,707
Lemon		<i>Unspecified</i>	19	+16	6,411	+5,500
		Eureka	292	-115	110,136	-64,171
		Eureka Seedless	46	+46	21,834	+21,834
		Fino	3	0	964	0
		Lemonade	0	0	50	-63
		Limonera	2	0	890	0
		Lisbon	60	0	16,518	-195
Lime		<i>Unspecified</i>	23	+22	11,470	+10,520
		Tahitian	56	-17	17,481	-13,821
Mandarin	Mandarin	<i>Unspecified</i>		-1		-550
	Mandarin early	Fremont	28	-25	14,283	-11,864
		Imperial	917	-165	367,999	-93,379
		Miho Satsuma	0	-1	0	-600
		Nova	40	-79	16,896	-36,563
		Mandarin early season total	1,023	-232	414,530	-127,054
	Mandarin mid	Afourer	93	+85	41,887	+37,488
		Avana Tardivo	30	+30	10,921	+10,921
		Daisy	26	+14	13,224	+7,308
		Ellendale	24	-166	8,635	-47,009
		Ellenor	7	-34	3,787	-11,042
		Empress	46	+9	15,165	+2,750
		Golden Nugget	4	0	1,849	+1,849
		Hickson	141	-102	53,552	-37,234
		Monarch	3	0	1,094	0
		Page	0	-5	0	-1,243
		Success	9	-12	3,457	-4,273
		Sunburst	20	-35	11,730	-17,764
		Taylor Lee	59	-71	27,129	-27,214
		Mandarin mid season total	468	-277	193,161	-84,732
	Mandarin late	Murcott	1,060	-415	465,771	-195,509
		Murcott Honey	26	+26	15,666	+15,666
		Murcott LS	261	+261	116,203	+116,203
		Topaz	1	-1	200	-307
		Mandarin late season total	1,349	-128	598,131	-63,656
	Mandarin total		2,840	-638	1,205,822	-275,992
Navel	Navel early season	Navelina	19	-36	9,242	-15,875
		Nucellar Leng	1	0	280	0
		Pasin	<1	0	200	+200
	mid season	Washington	99	-195	30,822	-49,676
	late season	Late Lane	0	-2		-584
	Navel total		119	-233	40,544	-65,935

Queensland change 2003 to 2008 continued

CATEGORY		VARIETY	2011 Hectare	Change since 2003	2011 Trees	Change since 2003
Orange	Sweet orange	Honey Ball	12	+12	7,443	+7,443
		Joppa	5	-3	1,576	-1,039
	Blood orange	Arnold Blood	2	1	1,102	473
Pummelo		Pummelo	0	-1	143	+31
Tangelo		Minneola	9	-11	4,086	-6,295
Valencia	Valencia	Valencia	12	-31	3,278	-8,021
		Valencia Late	23	-57	6,591	-16,787
	Seedless Valencia	Midnight	12	+1	5,461	+663
TOTAL			3,592	-1,057	1,482,594	-421,301

1.6 Western Australia

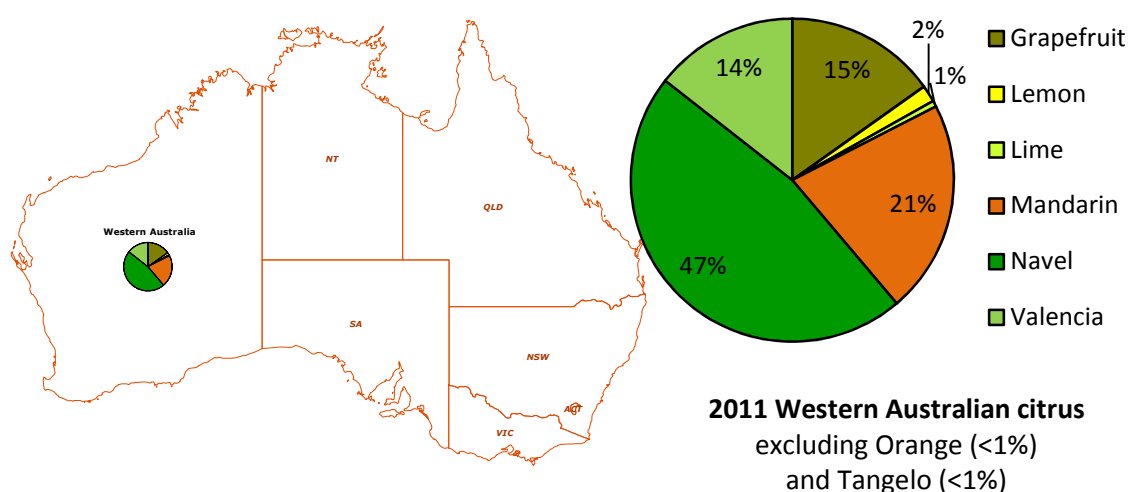
The 2011 citrus census of Western Australian was undertaken by SunRISE 21 in collaboration with Citrus Australia. Census survey maps, mapping and data entry were based on 2010 Landgate imagery, 2010 and 2011 NearMaps, and 2010 and 2011 Google Earth.

1.6.1 Western Australia citrus

In summary for Western Australian citrus:

- In 2011; 1,561 hectares of citrus (813,433 trees) across 184 citrus properties were mapped and 292 hectares were new plantings since 2008. New plantings are predominantly navels
- The area of citrus has increased from 1,042 hectares in 2003 to 1,356 hectares in 2008, then 1,561 hectares in 2011; a 50% increase from 2003 to 2011
- The number of citrus trees has increased from 463,702 in 2003 to 671,748 in 2008, then to 813,433 trees in 2011; a 75% increase from 2003 to 2011
- Western Australia citrus growers predominantly grow Late Lane and Washington navels, Valencia oranges and Imperial mandarins
- Western Australian citrus is predominantly drip irrigation and grown on Troyer rootstock.
- The number of citrus growers has declined from 209 growers in 2003 to 190 in 2008, then 184 growers in 2011
- The average citrus area per property has increased from 5 hectares in 2003 to 7 hectares in 2008 then to 9 hectares in 2011

Figure 5 – Western Australia citrus

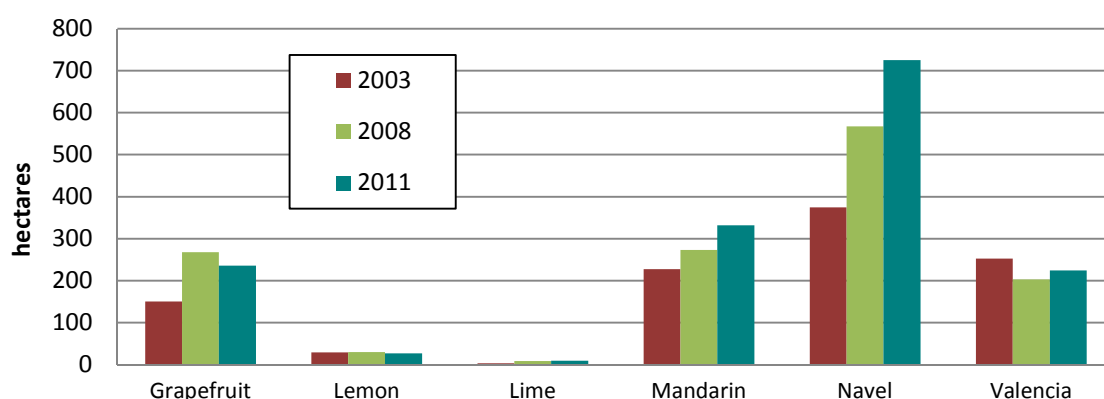


Western Australia citrus 2003 to 2011

The area of citrus in Western Australia has increased from 1,042 hectares in 2003 to 1,356 hectares in 2008 and then to 1,561 hectares in 2011. The overall change from 2003 to 2011 is a 50% increase in area planted (519 hectares) and an increase of 75% in tree numbers (349,731 trees) as shown in Table 19.

Table 19 – Western Australia citrus 2003 to 2011

Category	2003		2008		2011		Change 2003-2011	
	ha	trees	ha	trees	ha	trees	ha	trees
Grapefruit	150	50,473	268	89,228	235	79,062	+85	+28,589
Lemon	28	15,590	30	15,601	26	14,460	-2	-1,130
Lime	3	979	8	3,171	9	3,689	+6	+2,710
Mandarin	227	112,341	273	147,165	332	189,285	+104	+76,944
Navel	375	184,293	568	314,080	726	410,431	+351	+226,137
Orange	1	446	2	1,279	2	1,230	+1	+785
Pummelo	0	10	0	10	0	9	0	-1
Tangelo	5	2,405	5	2,213	7	3,576	+2	+1,172
Valencia	252	97,165	203	99,004	224	111,690	-29	+14,525
Total	1,042	463,702	1,356	671,748	1,561	813,433	+519 +50%	+349,731 +75%
Average	445 trees/ha		495 trees/ha		521 trees/ha			



Note: 7% of citrus categories are unknown. A linear extrapolation was applied to account for the 7%
Tree numbers are estimates from a range of sources; grower input, calculations & counts from imagery

Dominant variety

The dominant citrus variety in Western Australia changed from Valencia in 2003 to Late Lane navel in 2008 and 2011

	Dominant variety		
	2003	2008	2011
1	Valencia	LateLane	LateLane
2	Washington	Valencia	Washington
3	LateLane	Washington	Valencia
4	Imperial	RioRed	Imperial
5	Flame	Flame	RioRed

Western Australia citrus rootstocks, irrigation and properties

Western Australia citrus is predominantly drip irrigated and grown on a Troyer rootstock as shown in Table 20.

Table 20 – Western Australia trees per hectare (bearing and non-bearing), dominant rootstock and irrigation type

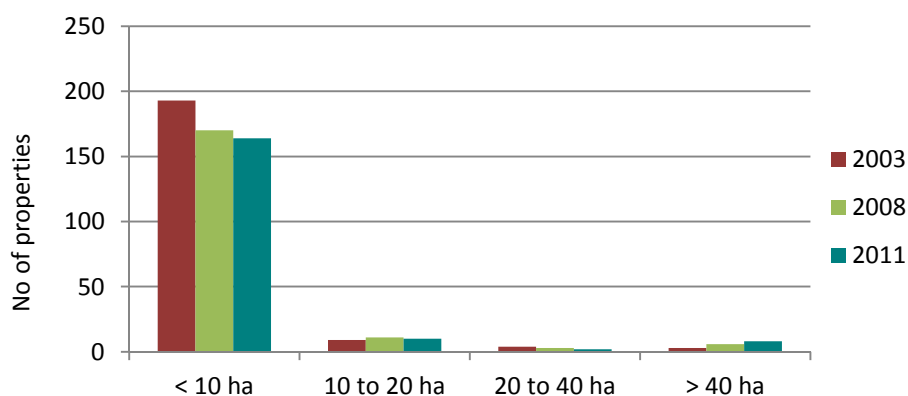
	2011 Trees/ha		Dominant rootstock 2011	Dominant irrigation		
	Non-bearing	bearing		2003	2008	2011
Grapefruit	458	344	Swingle	Low level	Low level	Low level
Lemon	636	539	Rough Lemon	Low level	Low level	Low level
Lime	397	455	Troyer	Low level	Drip	Drip
Mandarin	637	540	Troyer	Drip	Drip	Drip
Navel	613	538	Troyer	Low level	Low level	Drip
Orange	354	664	Swingle	Low level	Drip	Drip
Pummelo	0	571	Trifoliata	Drip	Drip	Drip
Tangelo	546	512	Troyer	Low level	Low level	Low level
Valencia	646	469	Troyer	Drip	Drip	Drip
Total	619	455	Troyer	Low level	Drip	Drip

Western Australia citrus properties

While the number of citrus growers declined by 25 between 2003 and 2011; the average property size increased from 5.0 hectares to 8.5 hectares of citrus per property as shown in Table 21.

Table 21 – Western Australia citrus properties

Property size (citrus area)	Number of properties			Change 2003 to 2011	
	2003	2008	2011	properties	% of 2003
< 10 ha	193	170	164	-29	-14%
10 to 20 ha	9	11	10	+1	0%
20 to 40 ha	4	3	2	-2	-1%
> 40 ha	3	6	8	+5	+2%
Total properties	209	190	184	-25	-12%
Average property size (ha of citrus)	5.0	7.1	8.5		



Map 5 – Western Australia citrus map



1.6.2 Western Australia 2011 citrus varieties

CATEGORY		VARIETY	2011 HECTARES			
			Bearing*	Non-Bearing	Total	
Citrus		<i>not surveyed</i>	102	9	111	7%
Grapefruit	Grapefruit white flesh	<i>unspecified</i>	<1	0	<1	0%
		Marsh	2	0	2	0%
	Grapefruit pink & red flesh	Flame	98	1	98	6%
		Henderson	1	0	1	0%
		Ray Ruby	9	0	9	1%
		Rio Red	99	3	103	7%
		Ruby, Redblush	<1	0	<1	0%
		Star Ruby	4	0	4	0%
Lemon	<i>unspecified</i>	4	0	4	0%	
	Eureka	14	6	20	1%	
	Meyer	1	0	1	0%	
	Verna	<1	0	<1	0%	
Lime	<i>unspecified</i>	<1	0	<1	0%	
	Tahitian	2	7	8	1%	
	West Indian	0	0	0	0%	
Mandarin	Mandarin	<i>unspecified</i>	3	0	3	0%
	Mandarin early	Caffin Clementine	0	1	1	0%
		Clementine	5	3	8	1%
		Imperial	72	41	113	7%
		Marisol Clementine	1	0	1	0%
		Miho Wase Satsuma	0	<1	<1	0%
		Nules	8	18	27	2%
		Okitsu Wase Satsuma	0	<1	<1	0%
		Satsuma	1	0	2	0%
	Mandarin early season total		88	64	152	10%
	Mandarin mid	Afourer	0	37	38	2%
		Avana Tardivo	0	<1	<1	0%
		Daisy	3	13	16	1%
		Darling	1	0	1	0%
		Dancy	1	0	1	0%
		Ellendale	6	0	6	0%
		Hickson	26	23	49	3%
		Oroval	<1	0	<1	0%
		TDE Mandarin	0	<1	<1	0%
	Mandarin mid season total		38	73	111	7%
	Mandarin late	Emperor	2	0	3	0%
		Hansen	<1	0	<1	0%
		Kara	<1	0	<1	0%
		Murcott	10	0	10	1%
		Murcott Honey	1	0	1	0%
		Mystique	14	13	28	2%
		Topaz	<1	0	<1	0%
	Mandarin late season total		28	14	42	3%
Mandarin total		157	151	308	20%	

Western Australia 2011 citrus varieties continued

CATEGORY	VARIETY	2011 HECTARES			
		Bearing*	Non-Bearing	Total	
Navel	Navel	<i>unspecified</i>	<1	0	<1 0%
	Navel early	Atwood	0	2	2 0%
		Fukumoto	2	0	2 0%
		Leng	6	11	17 1%
		M7	0	15	15 1%
		Navelina	46	38	84 5%
		Newhall	13	42	55 3%
		Pasin	0	0	0 0%
		Rosey Red	1	3	5 0%
		Ryan	<1	0	<1 0%
		Thomson	<1	0	<1 0%
	Navel early season total		69	111	180 12%
	Navel mid	Cara Cara	9	18	27 2%
		Washington	81	114	195 13%
	Navel mid season total		90	132	222 14%
	Navel late	Autumn Gold	3	0	3 0%
		Barnfield	11	0	11 1%
		Chislett	8	24	32 2%
		Late Lane	91	118	209 13%
		Powell	5	0	5 0%
		Rohde	0	11	11 1%
		Wilson	<1	0	<1 0%
	Navel late season total		118	153	271 17%
	Navel total		277	397	674 43%
Orange	Blood Orange	<i>unspecified</i>	<1	0	<1 0%
	Sweet	Acidless Orange	0	<1	<1 0%
		Salustiana	1	0	1 0%
	Sour	Seville	<1	0	<1 0%
Pummelo	Pummelo	Pummelo	<1	0	<1 0%
Tangelo	Tangelo	<i>unspecified</i>	<1	0	<1 0%
		Minneola	4	3	6 0%
Valencia	Valencia	Benyenda	<1	0	<1 0%
		Berri	1	0	1 0%
		Keenan	<1	0	<1 0%
		Smith	<1	0	<1 0%
		Valencia	154	20	174 11%
	Valencia Seedless	Midnight	0	32	32 2%
		Valencia Seedless	1	0	1 0%
TOTAL		931	630	1,561	100%

*Bearing trees were planted six or more years ago (i.e. planted in 2005 or earlier) or were reworked three or more years ago (i.e. reworked in 2008 or earlier).

1.6.3 Western Australia change since 2003

CATEGORY		VARIETY	2011 hectare	Change since 2003	2011 trees	Change since 2003
Citrus		<i>not surveyed</i>	111	-53	35,817	-12,691
Grapefruit	Grapefruit white flesh	<i>unspecified</i>	<1	0	161	0
		Marsh	2	-4	972	-1,550
	Grapefruit	Flame	98	+48	37,907	+18,788
	Red flesh	Henderson	1	-1	400	-275
		Ray Ruby	9	-2	2,179	-554
		Rio Red	103	+52	32,688	+14,148
		Ruby, Redblush	<1	0	64	-10
		Star Ruby	4	0	1,210	-159
Lemon	<i>unspecified</i>	4		1,846	+130	
	Eureka	20	0	11,599	-198	
	Meyer	1	0	300	0	
	Verna	<1	0	78	-68	
Lime	<i>unspecified</i>	0	0	90	+90	
	Tahitian	8	+6	3,437	+2,685	
	West Indian	0	0	0	-125	
Mandarin	Mandarin	<i>unspecified</i>	3	0	541	0
	Mandarin early	Caffin Clementine	1	0	800	+800
		Clementine	8	+5	4,001	+2,753
		Imperial	113	+18	64,270	+15,526
		Marisol Clementine	1	0	540	-126
		Miho Wase Satsuma	1	0	430	+200
		Nules	27	+18	15,291	+10,403
		Okitsu Wase Satsuma	1	-1	200	-450
		Satsuma	2	0	948	-139
	Mandarin early season total		152	42	86,480	28,967
	Mandarin mid	Afourer	38	+38	25,296	+25,296
		Avana Tardivo	<1	0	244	+244
		Daisy	16	+13	10,020	+7,580
		Darling	1	0	260	0
		Dancy	1	0	492	-40
		Ellendale	6	-4	2,567	-1,518
		Hickson	49	+17	28,912	+11,257
		Parker	0	0	0	-40
		Oroval	<1	0	300	0
		TDE Mandarin	<1	0	400	+400
	Mandarin mid season total		111	64	68,491	43,179
	Mandarin late	Emperor	3	-2	1,095	-766
		Hansen	0	0	21	-115
		Kara	0	0	40	-25
		Murcott	10	-3	6,323	-1,288
		Murcott Honey	1	0	650	0
		Mystique	28	+16	17,129	+10,409
		Topaz	<1	0	180	0
	Mandarin late season total		42	11	25,438	8,215
Mandarin Total		308	117	180,950	80,361	

Western Australia change since 2003 continued

Western Australia change since 2003 continued						
CATEGORY		VARIETY	2011 hectare	Change since 2003	2011 trees	Change since 2003
Navel	Navel	unspecified	<1	0	90	+90
	Navel early	Atwood	2	+2	900	+900
		Fukumoto	2	0	1,000	0
		Leng	17	+10	11,139	+8,400
		M7	15	+15	11,000	+11,000
		Navelina	84	+31	46,140	+18,100
		Newhall	55	+50	31,697	+28,410
		Pasin	0	0	0	-125
		Rosey Red	5	+4	2,679	+2,373
		Ryan	<1	0	200	0
		Thomson	<1	0	25	0
	Navel early Total		180	112	104,905	69,183
	Navel mid	Cara Cara	27	+18	16,603	+11,048
		Washington	195	+87	114,201	+59,677
	Navel mid Total		222	106	130,804	70,725
	Navel late	Autumn Gold	3	+1	1,350	+350
		Barnfield	11	0	6,552	-126
		Chislett	32	+24	17,860	+12,628
		Late Lane	209	+112	122,770	+73,236
		Powell	5	-5	2,221	-3,061
		Rohde	11	+11	5,471	+5,319
		Summer Gold	0	-2	0	-1,000
		Wilson	<1	0	336	0
	Navel late Total		271	140	156,560	87,346
	Navel Total			674	358	392,359
Orange	Blood Orange	unspecified	<1	0	29	0
	Sweet	Acidless Orange	<1	0	230	+110
		Salustiana	1	+1	892	+667
	Sour	Seville	<1	0	25	0
Pummelo	Pummelo	Pummelo	<1	0	9	0
Tangelo		unspecified	<1	0	68	0
		Minneola	6	+2	3,351	+1,266
Valencia	Valencia	Benyenda	<1	0	125	0
		Berri	1	+1	500	+500
		Keenan	<1	0	94	0
		Smith	<1	0	120	0
		Valencia	174	-37	81,869	-4,386
	Seedless Valencia	Midnight	32	+32	23,733	+23,733
		Valencia Seedless	1	0	332	-75
TOTAL			1,561	+519	813,433	+349,731

1.7 Central NSW

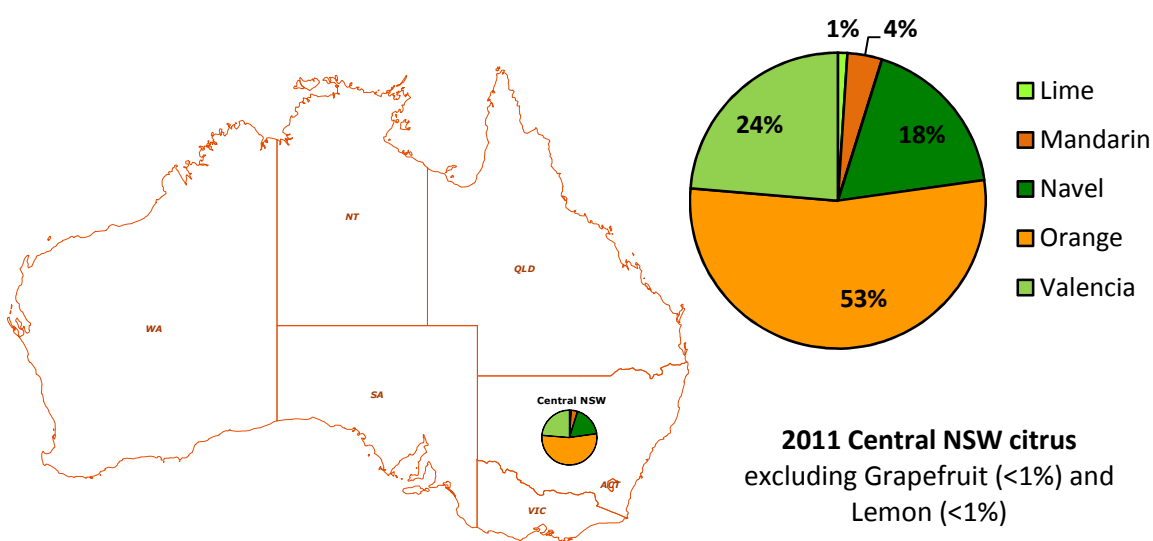
Surveys of Central NSW citrus growers were undertaken in collaboration with Nathan Hancock from Citrus Australia. The survey maps were printed by SunRISE 21, emailed to Nathan who contacted growers from these regions. Growers marked changes on the maps and emailed or faxed to Nathan, then he forwarded to SunRISE21 for data entry. The survey maps and 2011 data entry were based on 2004 and 2010 Google Earth. Five new properties (516 hectares) at Moree, Forbes and Gunnedah were added to the National Plantings Database.

1.7.1 Central NSW citrus

In summary for Central NSW citrus:

- In 2011; 875 hectares of citrus (515,561 trees) across 15 citrus properties were mapped and 230 hectares were new plantings since 2008. New plantings are predominantly Common Orange and Valencia
- The area of citrus has increased from 638 hectares in 2003 to 643 hectares in 2008 and a further increase to 875 hectares in 2011. This increase is due to the additional regions of Moree, Forbes and Gunnedah
- The number of citrus trees has increased from 343,929 in 2003 to 372,842 in 2008, and 515,561 trees in 2011
- Central NSW predominantly grow Salustiana and Hamlin Common Orange
- Central NSW citrus is predominantly drip irrigated and grown on a Trifoliata rootstock
- The number of citrus growers remained the same at 14 growers in 2003 and 2008, then increased by 1 to 15 growers in 2011
- The average citrus area per property remained the same at 46 hectares in 2003 and 2008 then increased to 58 hectares in 2011

Figure 6 – Central NSW citrus

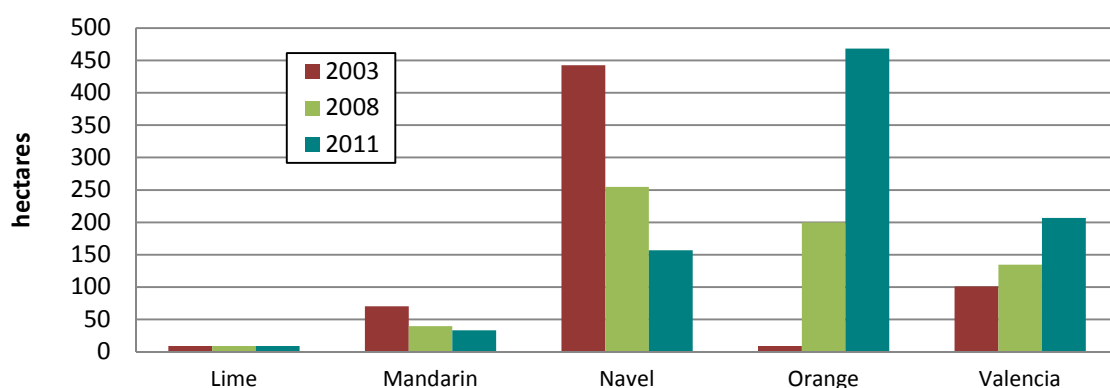


Central NSW citrus 2003 to 2011

The area of citrus in central NSW increased from 638 hectares in 2003 to 643 hectares in 2008 and 875 hectares in 2011. The overall change from 2003 to 2011 is a 37% increase in area planted (237 hectares) and a 50% increase in tree numbers (171,632 trees) as shown in Table 22.

Table 22 – Central NSW citrus 2003 to 2011

Category	2003		2008		2011		Change 2003-2011	
	ha	trees	ha	trees	ha	trees	ha	trees
Grapefruit	1	423	1	421	1	417	0	-6
Lemon	4	2,034	4	2,023	0	0	-4	-2,034
Lime	9	4,068	9	4,046	9	4,010	0	-58
Mandarin	71	45,920	40	28,312	33	23,532	-37	-22,388
Navel	443	256,276	255	148,158	157	86,739	-286	-169,537
Orange	9	6,669	200	130,362	468	297,410	+459	+290,742
Pummelo	-	-	-	-	-	-	-	-
Tangelo	-	-	-	-	-	-	-	-
Valencia	101	28,538	135	59,520	207	103,452	+106	+74,914
Total	638	343,929	643	372,842	875	515,561	+237 +37%	+171,632 +50%
Average	539 trees/ha		580 trees/ha		589 trees/ha			



Note: Tree numbers are estimates from a range of sources; grower input, calculations & counts from imagery

Dominant variety

The dominant Central NSW citrus variety changed from Navelina in 2003 to Hamlin in 2008 and Salustiana in 2011

	Dominant variety		
	2003	2008	2011
1	Navelina	Hamlin	Salustiana
2	Washington	Navelina	Hamlin
3	Valencia	Washington	Washington
4	Leng	Salustiana	Valencia
5	Late Lane	Valencia	McMahon

Central NSW citrus rootstocks, irrigation and properties

Central NSW citrus is predominantly drip irrigated and grown on a trifoliata rootstock as shown in Table 23.

Table 23 – Central NSW trees per hectare (bearing and non-bearing), dominant rootstock and irrigation type

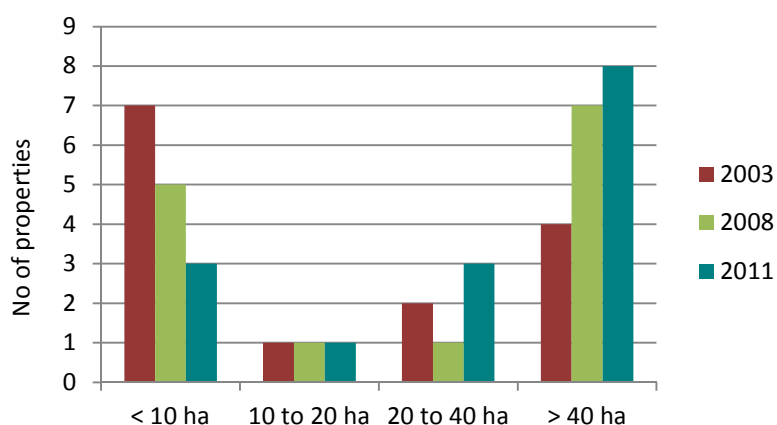
	2011 Trees/ha		Dominant rootstock 2011	Dominant irrigation		
	Non-bearing	bearing		2003	2008	2011
Grapefruit	0	416	Troyer	Overhead	Overhead	Overhead
Lemon	0	0		Drip	Drip	
Lime	0	444	Trifoliata	Drip	Drip	Drip
Mandarin	0	711	Troyer	Drip	Drip	Drip
Navel	0	555	Trifoliata	Drip	Drip	Drip
Orange	645	599	Citrango	Drip	Drip	Drip
Pummelo	0	0	-	-	-	-
Tangelo	0	0	-	-	-	-
Valencia	668	290	Citrango	Overhead	Overhead	Drip
Total	650	509	Trifoliata	Drip	Drip	Drip

Central NSW citrus properties

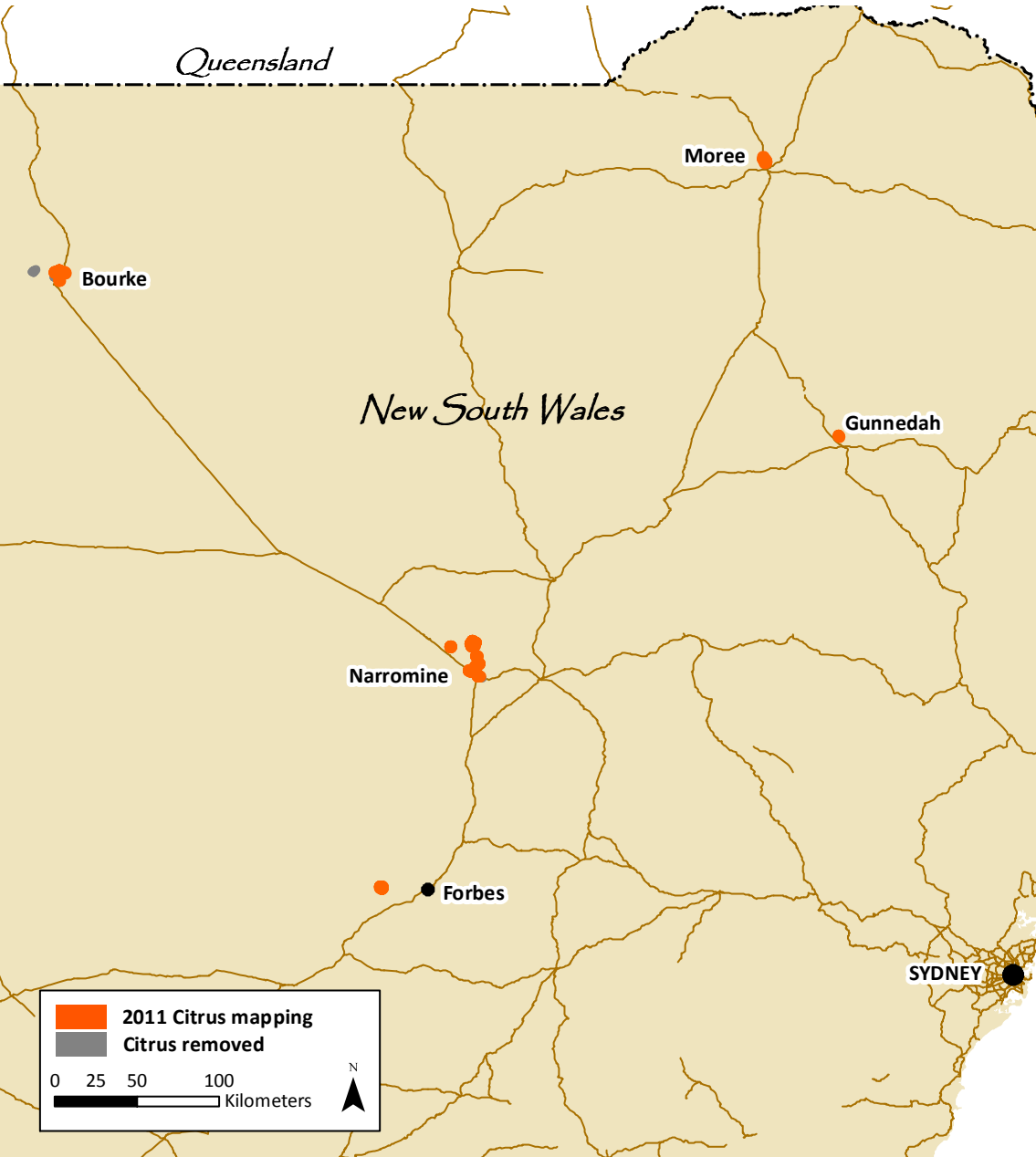
While the number of citrus growers increased by one; the average property size increased from 45.6 to 58.3 hectares of citrus as shown in Table 24.

Table 24 – Central NSW citrus properties

Property size (citrus area)	Number of properties			Change 2003 to 2011	
	2003	2008	2011	properties	% of 2003
< 10 ha	7	5	3	-4	-29%
10 to 20 ha	1	1	1	0	0%
20 to 40 ha	2	1	3	+1	+7%
> 40 ha	4	7	8	+4	+29%
Total properties	14	14	15	+1	+7%
Average property size (ha of citrus)	45.6	45.9	58.3		



Map 6 – Central NSW citrus map



1.7.2 Central NSW 2011 citrus varieties

CATEGORY		VARIETY	2011 HECTARES			
			Bearing*	Non-bearing	Total	
Citrus		<i>not surveyed</i>	4	0	4	0%
Grapefruit		Marsh	1	0	1	0%
Lime		Tahitian	9	0	9	1%
Mandarin	Mandarin early	Amigo	0	0	0	0%
		Imperial	25	0	25	3%
	Mandarin late	Murcott	8	0	8	1%
Mandarin total			33	0	33	4%
Navel	Navel early	Fisher	13	0	13	1%
		Fukumoto	0	0	0	0%
		Leng	11	0	11	1%
		Navelina	38	0	38	4%
		Newhall	6	0	6	1%
		Ryan	4	0	4	0%
		Thomson	0	0	0	0%
		Navel early season total		72	0	72
	Navel mid	Palmer	2	0	2	0%
		Washington	62	0	62	7%
	Navel mid season total		64	0	64	7%
	Navel late	Barnfield	0	0	0	0%
		Chislett	3	0	3	0%
		Late Lane	17	0	17	2%
	Navel late season total		20	0	20	2%
	Navel total			156	0	156
Orange	Orange	Hamlin	12	174	186	21%
		Pineapple	0	39	39	4%
		Salustiana	73	168	241	28%
	Blood Orange	Blood Orange	<1	0	>1	0%
Valencia	Valencia	Ben Yenda	0	32	32	4%
		Keenan	0	31	31	4%
		Valencia	68	0	68	8%
	Valencia-Seedless	McMahon	0	52	52	6%
		Valencia Seedless	23	0	23	3%
TOTAL			379	496	875	100%

*Bearing trees were planted six or more years ago or were reworked three or more years ago

1.7.3 Central NSW change since 2003

CATEGORY		VARIETY	2011 hectare	Change since 2003	2011 trees	Change since 2003
Citrus		<i>not surveyed</i>	4	-10	1,280	-4,490
Grapefruit		Marsh	1	0	416	0
Lemon		Eureka	0	-4	0	-2,000
Lime		Tahitian	9	0	4,000	0
Mandarin	Mandarin early	Amigo	0	-1	0	-736
		Imperial	25	-16	17,638	-9,920
	Mandarin late	Murcott	8	-19	5,836	-11,020
Mandarin total			33	-36	23,474	-21,676
Navel	Navel early	Fisher	13	-12	7,662	-8,122
		Fukumoto	0	-1	0	-315
		Leng	11	-62	4,088	-40,572
		Navelina	38	-133	31,542	-75,417
		Newhall	6	-12	4,159	-7,707
		Ryan	4	-3	2,316	-2,000
		Thomson	0	-2	0	-1,700
	Navel early season total		72	-225	49,767	-135,833
	Navel mid	Palmer	2	0	500	0
		Washington	62	-20	28,134	-7,178
	Navel mid season total		64	-20	28,634	-7,178
	Navel late	Barnfield	0	-3	0	-1,590
		Chislett	3	-3	960	-1,600
		Late Lane	17	-26	7,163	-19,252
Navel late season total		20	-32	8,123	-22,442	
Navel Total			156	-277	86,524	-165,453
Orange	Orange	Hamlin	186	+177	131,870	+125,363
		Pineapple	39	+39	29,800	+29,800
		Salustiana	241	+241	134,952	+134,952
	Blood Orange	Blood Orange	<1	0	50	0
Valencia	Valencia	Ben Yenda	32	+32	18,228	+18,228
		Keenan	31	+31	17,657	+17,657
		Valencia	68	-8	17,232	-1,699
	Valencia-Seedless	McMahon	52	+52	40,950	+40,950
		Valencia Seedless	23	0	9,128	0
TOTAL			875	+237	515,561	+171,632

1.8 East Coast NSW

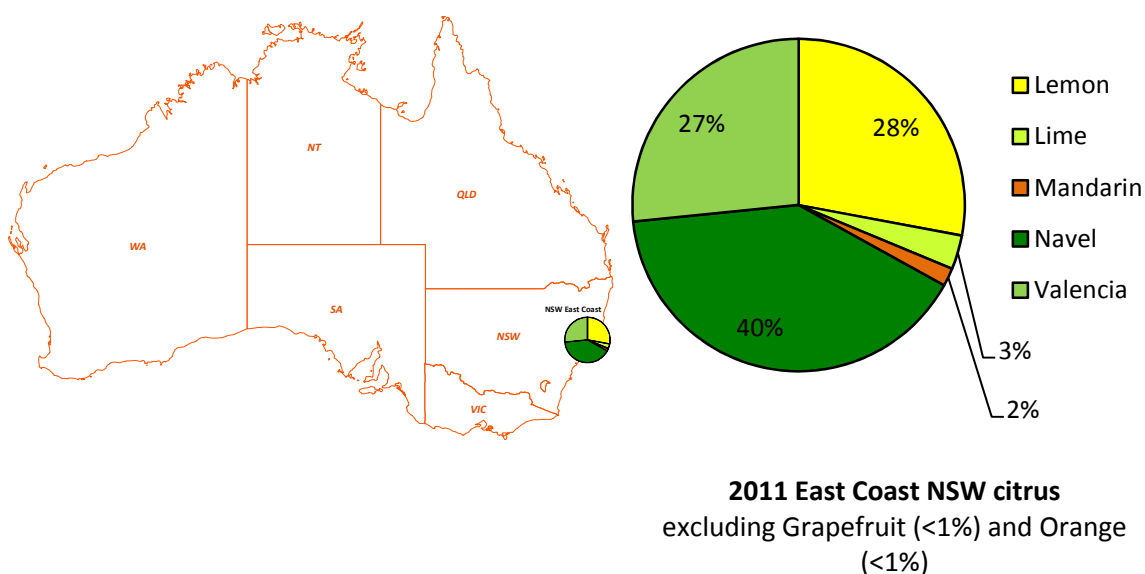
Grower surveys for East Coast NSW (north and central coasts) were undertaken by SunRISE 21. Survey maps were printed and posted directly to growers with stamped addressed envelopes for survey returns. Some growers were contacted personally by telephone or email. The survey maps and data entry were based on Google Earth 2010 and NearMap 2010 imagery.

1.8.1 East Coast NSW citrus

In summary for East Coast NSW citrus:

- In 2011; 368 hectares of citrus (202,422 trees) across 69 citrus properties were mapped and 4 hectares were new plantings since 2008. New plantings are predominantly Eureka lemon
- The area of citrus declined from 555 hectares in 2003 to 403 hectares in 2008 and 368 hectares in 2011
- The number of citrus trees declined from 325,022 in 2003 to 230,893 in 2008, and 202,422 trees in 2011
- NSW east coast predominantly grow Washington navels, Eureka lemons and Valencia oranges
- NSW east coast citrus is predominantly irrigated with low level sprinklers and grown on a Trifoliata rootstock
- The number of citrus growers declined from 79 growers in 2003 to 68 in 2008, then increased by 1 to 69 growers in 2011
- The average citrus area per property decreased from 7 hectares in 2003 to 6 hectares in 2008 and 5.3 hectares in 2011

Figure 7 – East Coast NSW citrus

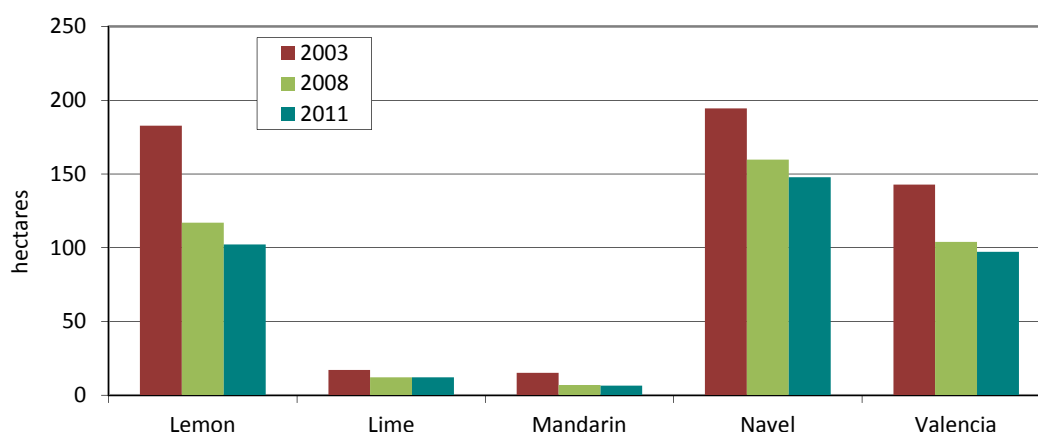


East Coast NSW citrus 2003 to 2011

The area of citrus in the NSW east coast declined from 555 hectares in 2003 to 403 hectares in 2008 and 368 hectares in 2011. The overall change from 2003 to 2011 is a 34% decline in area planted (-187 hectares) and a 38% decrease in tree numbers (-122,600 trees) as shown in Table 25.

Table 25 – East Coast NSW citrus 2003 to 2011

Category	2003		2008		2011		Change 2003-2011	
	ha	trees	ha	trees	ha	trees	ha	trees
Grapefruit	1	451	1	462	1	322	0	-129
Lemon	183	100,156	117	59,293	102	51,482	-81	-48,674
Lime	17	9,548	12	7,288	12	7,338	-5	-2,210
Mandarin	15	9,818	7	3,505	6	3,315	-9	-6,503
Navel	195	116,629	160	95,923	148	82,960	-47	-33,668
Orange	2	902	2	1,282	2	988	0	+86
Tangelo	0	802	0	82	0	83	0	-719
Valencia	143	86,715	104	63,057	97	55,932	-46	-30,783
Total	555	325,022	403	230,893	368	202,422	-187 -34%	-122,600 -38%
Average	585 trees/ha		573 trees/ha		550 trees/ha			



Note: 4% of citrus categories are unknown. A linear extrapolation was applied to account for the 4% Tree numbers are estimates from a range of sources; grower input, calculations & counts from imagery

Dominant variety

The dominant East Coast NSW citrus variety changed from Eureka lemon in 2003 to Washington navel in 2008 and 2011

Dominant variety			
	2003	2008	2011
1	Eureka	Washington	Washington
2	Washington	Eureka	Eureka
3	Valencia	Valencia	Valencia
4	Late Lane	Late Lane	Late Lane
5	Tahitian	Tahitian	Tahitian

East Coast NSW citrus rootstocks, irrigation and properties

NSW east coast citrus is predominantly irrigated with low level sprays and grown on a trifoliata rootstock as shown in Table 26.

Table 26 – East Coast NSW dominant rootstock and irrigation type

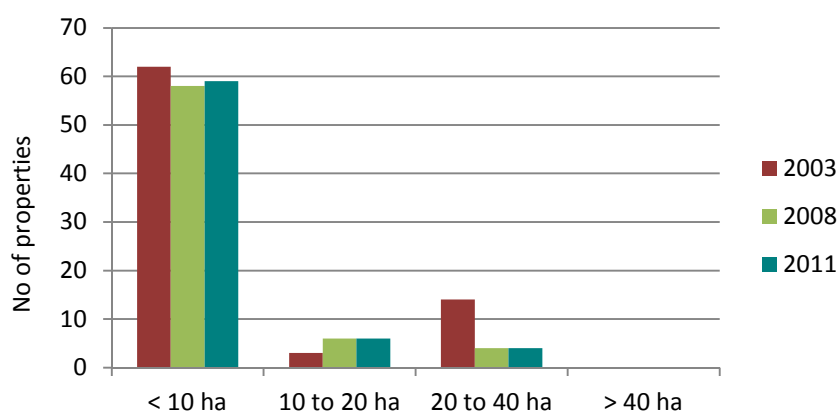
	2011 Trees/ha		Dominant rootstock 2011	Dominant irrigation		
	Non-bearing	bearing		2003	2008	2011
Grapefruit	0	491	Trifoliata	Low level	Low level	Low level
Lemon	436	506	Rough Lemon	Low level	Low level	Low level
Lime	0	602	Trifoliata	Low level	Low level	Low level
Mandarin	0	517	Trifoliata	Low level	Low level	Low level
Navel	814	556	Trifoliata	Low level	Low level	Low level
Orange	624	508	Trifoliata	Low level	Low level	Low level
Pummelo	-	-	-	-	-	-
Tangelo	0	618	Trifoliata	Low level	Low level	Low level
Valencia	0	575	Trifoliata	Low level	Low level	Low level
Total	625	547	Trifoliata	Low level	Low level	Low level

East Coast citrus properties

The number of citrus growers declined by 10 between 2003 and 2011; the average property size decreased from 7.0 to 5.3 hectares of citrus as shown in Table 27.

Table 27 – East Coast NSW citrus properties

Property size (citrus area)	Number of properties			Change 2003 to 2011	
	2003	2008	2011	properties	% of 2003
< 10 ha	62	58	59	-3	-4%
10 to 20 ha	3	6	6	+3	+4%
20 to 40 ha	14	4	4	-10	-13%
> 40 ha	0	0	0	0	-
Total properties	79	68	69	-10	-13%
Average property size (ha of citrus)	7.0	5.9	5.3		



Map 7 – East Coast NSW citrus map



1.8.2 East Coast NSW 2011 citrus varieties

CATEGORY		VARIETY	2011 HECTARES			
			Bearing*	Non Bearing	Total	
Citrus		<i>not surveyed</i>	8	5	14	4%
Grapefruit	Grapefruit	Rio Red	<1	0	<1	0%
	pink & red flesh	Ruby, Redblush	<1	0	<1	0%
Lemon		<i>unspecified</i>	<1	0	<1	0%
		Eureka	91	5	95	26%
		Francovielo	0	0	0	0%
		Lemonade	1	0	1	0%
		Lisbon	1	0	1	0%
		Meyer	1	0	1	0%
		Verna	0	0	0	0%
		Yen Ben	<1	0	<1	0%
Lime		Kaffir	<1	0	<1	0%
		Tahitian	10	0	10	3%
		West Indian	2	0	2	1%
Mandarin	Mandarin	<i>unspecified</i>	0	0	0	0%
	Mandarin early	Clementine	0	0	0	0%
		Fina Clementine	0	0	0	0%
		Imperial	2	0	2	1%
		Marisol Clementine	0	0	0	0%
		Nova	<1	0	<1	0%
		Okitsu Wase satsuma	1	0	1	0%
		Silverhill satsuma	<1	0	<1	0%
		Mandarin early season total	3	0	3	1%
	Mandarin mid	Hickson	<1	0	<1	0%
	Mandarin late	Emperor	1	0	1	0%
		Murcott	2	0	2	1%
	Mandarin late season total		3	0	3	1%
	Mandarin total		6	0	6	2%
Navel	Navel early	Leng	0	0	0	0%
		Navelina	4	0	4	1%
		Newhall	4	0	4	1%
		Ryan	1	0	1	0%
	Navel early season total		8	0	8	2%
	Navel mid	Bellamy	<1	0	<1	0%
		Washington	109	3	112	30%
	Navel mid season total		110	2	112	30%
	Navel late	Barnfield	0	0	0	0%
		Late Lane	22	0	22	6%
		Powell	<1	0	<1	0%
	Navel late season total		22	0	22	6%
	Navel total		140	2	142	39%
Orange misc.	Blood orange	<i>unspecified</i>	<1	0	<1	0%
	sweet	Hamlin	0	1	1	0%
	sour	Seville	1	0	1	0%
Tangelo		Seminole	<1	0	<1	0%
Valencia		Valencia	94	0	94	25%
TOTAL			355	13	368	100%

*Bearing trees were planted six or more years ago (i.e. planted in 2005 or earlier) or were reworked three or more years ago (i.e. reworked in 2008 or earlier).

East Coast NSW change since 2003

CATEGORY		VARIETY	2011 Hectare	Change since 2003	2011 Trees	Change since 2003
Citrus		<i>not surveyed</i>	14	+13	7,814	+6,928
Grapefruit	Grapefruit	Rio Red	<1	0	210	0
	pink & red flesh	Ruby, Redblush	<1	0	100	-140
Lemon		<i>unspecified</i>	<1	0	165	0
		Eureka	95	-80	47,855	-47,943
		Francovielo	0	0	0	-120
		Lemonade	1	0	450	0
		Lisbon	1	0	645	0
		Meyer	1	-3	180	-1,790
		Verna	0	-1	0	-535
		Yen Ben	<1	0	200	0
Lime		Kaffir	<1	-1	252	-50
		Tahitian	10	-5	6,008	-2,417
		West Indian	2	0	795	0
Mandarin	Mandarin	<i>unspecified</i>	0	0	0	-225
	Mandarin early	Clementine	0	-1	0	-250
		Fina Clementine	0	0	0	-132
		Imperial	2	-6	1,600	-4,305
		Marisol Clementine	0	0	0	-150
		Nova	<1	0	47	-50
		Okitsu Wase satsuma	<1	0	400	0
		Silverhill satsuma	<1	0	80	-132
		Mandarin early season total	3	-7	2,127	-5,019
	Mandarin mid	Hickson	<1	0	160	0
	Mandarin late	Emperor	1	0	400	0
		Murcott	2	-2	500	-1,360
		Mandarin late season total	3	-2	900	-1,360
	Mandarin total		6	-9	3,187	-6,604
Navel	early season	Leng	0	-2	0	-500
		Navelina	4	-4	1,583	-2,145
		Newhall	4	0	2,380	-117
		Ryan	1	-2	1,330	-400
		Navel early season total	8	-8	5,293	-3,162
	mid season	Bellamy	<1	0	69	0
		Washington	112	-40	58,585	-29,702
		Navel mid season total	112	-40	58,654	-29,702
	late season	Barnfield	0	-1	0	-54
		Late Lane	22	-3	15,611	-3,635
		Powell	<1	0	200	0
		Navel late season total	22	-4	15,811	-3,689
	Navel total		142	-52	79,758	-36,553
Orange	Blood orange	<i>unspecified</i>	<1	0	300	-300
	sweet	Hamlin	1	+1	350	+350
	sour	Seville	1	0	300	0
Tangelo		Seminole	<1	0	80	-720
Valencia		Valencia	94	-49	53,773	-32,706
TOTAL			368	-187	202,422	-122,600

1.9 Northern Territory

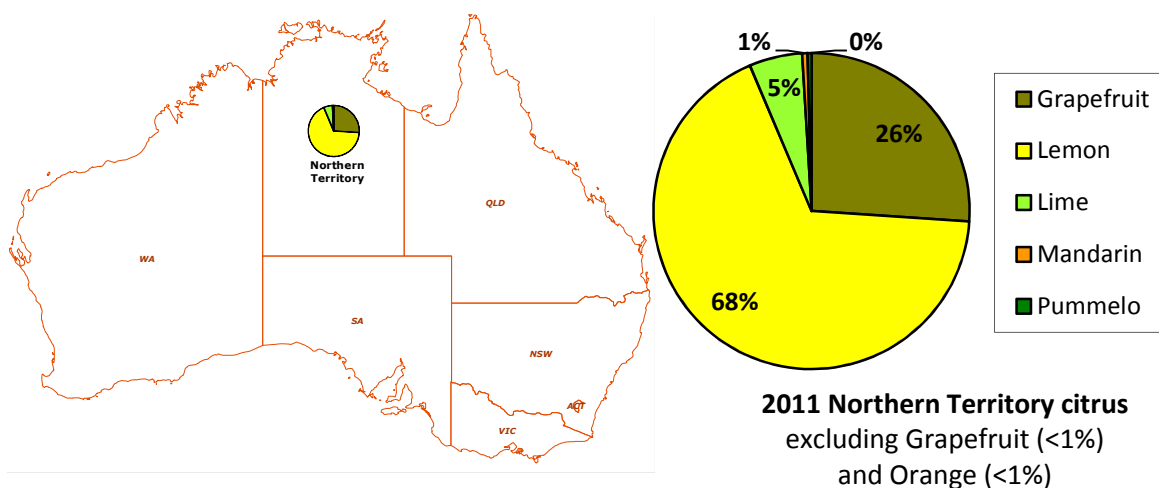
Survey maps for Northern Territory citrus growers were prepared by SunRISE 21 and posted to growers. Megan Connelly, Extension Officer, Department of Primary Industry, Fisheries and Mines NT assisted with grower contact details. Growers returned surveys by post or email to SunRISE 21. Mapping was based on 2010 Google Earth and 2003 orthophoto imagery acquired for the 2003 National Plantings Database.

1.9.1 Northern Territory citrus

In summary for Northern Territory citrus:

- In 2011; 137 hectares of citrus (47,746 trees) across 7 citrus properties were mapped and 42 hectares were new plantings since 2008. New plantings are predominantly Lemon and Lime
- The area of citrus declined from 232 hectares in 2003 to 207 hectares in 2008 and 137 hectares in 2011
- The number of citrus trees declined from 82,772 in 2003 to 72,963 in 2008, and 47,746 trees in 2011
- Northern Territory predominantly grows Eureka lemons, Lisbon lemons and Star Ruby grapefruit
- Northern Territory citrus is predominantly irrigated with low level sprinklers and grown on a Benton rootstock
- The number of citrus growers continues to decline with 30 growers in 2003, 16 in 2008 and 7 growers in 2011
- The average citrus area per property increased from 7.7 hectares in 2003 to 12.9 hectares in 2008 and 19.6 hectares in 2011

Figure 8 – Northern Territory citrus

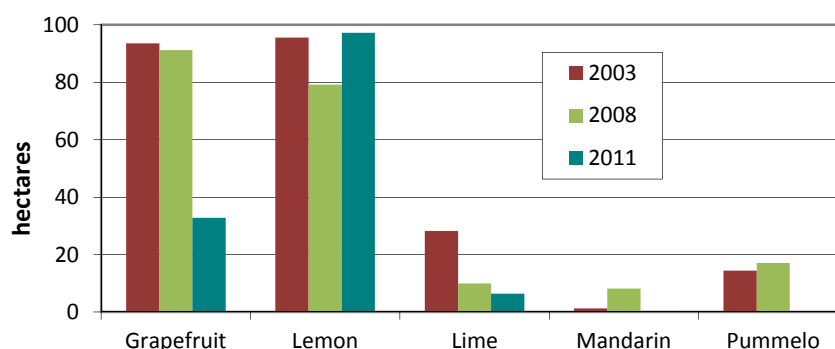


Northern Territory citrus 2003 to 2011

The area of citrus in the Northern Territory declined from 232 hectares in 2003 to 207 hectares in 2008 and 137 hectares in 2011. The overall change from 2003 to 2011 is a 41% decline in area planted (-95 hectares) and a 42% decrease in tree numbers (-35,026 trees) as shown in Table 28.

Table 28 – Northern Territory citrus 2003 to 2011

Category	2003		2008		2011		Change 2003-2011	
	ha	trees	ha	trees	ha	trees	ha	trees
Citron	-	-	-	-	-	-	-	-
Cumquat	-	-	-	-	-	-	-	-
Grapefruit	94	33,704	91	32,832	33	12,435	-61	-21,269
Lemon	96	33,068	79	27,610	97	32,265	+2	-803
Lime	28	10,562	10	3,135	6	2,596	-22	-7,966
Mandarin	1	372	8	4,130	0	250	-1	-122
Navel	-	-	-	-	-	-	-	-
Orange	-	-	-	-	-	-	-	-
Pummelo	14	5,066	17	5,255	0	200	-14	-4,866
Tangelo	-	-	-	-	-	-	-	-
Valencia	-	-	-	-	-	-	-	-
Total	233	82,772	205	72,962	137	47,746	-96 -41%	-35,026 -42%
Average	355 trees/ha		355 trees/ha		348 trees/ha			



Note: Tree numbers are estimates from a range of sources; grower input, calculations & counts from imagery

Dominant variety

The dominant citrus variety in the Northern Territory changed from Lisbon lemon in 2003 to Rio Red grapefruit in 2008 and Eureka lemon in 2011

Dominant variety			
	2003	2008	2011
1	Lisbon	Rio Red	Eureka
2	Rio Red	Eureka	Lisbon
3	Eureka	Lisbon	Star Ruby
4	Tahitian	Flame	Flame
5	Flame	Star Ruby	Tahitian

Northern Territory citrus rootstocks, irrigation and properties

Northern Territory citrus is predominantly irrigated with low level sprinklers and grown on a Benton rootstock as shown in Table 29.

Table 29 – Northern Territory dominant rootstock and irrigation type

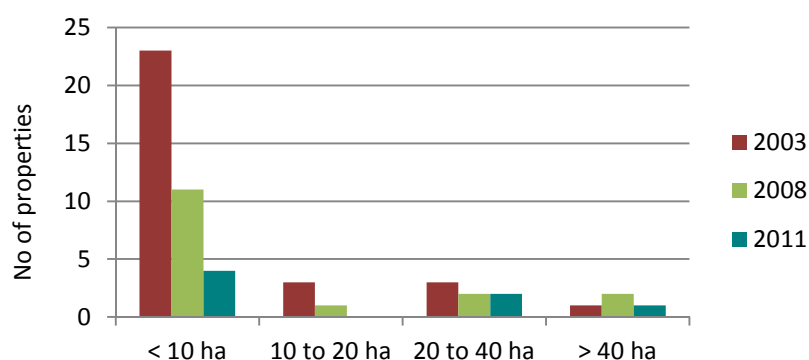
	2011 Trees/ha		Dominant rootstock 2011	Dominant irrigation		
	Non-bearing	bearing		2003	2008	2011
Grapefruit	0	379	Troyer	Low level	Low level	Low level
Lemon	305	353	Benton	Low level	Low level	Low level
Lime	414	402	Trifoliata	Low level	Low level	Low level
Mandarin	599	0	Troyer	Low level	Low level	Low level
Pummelo	994	0	Troyer	Low level	Low level	Low level
Total	315	365	Benton	Low level	Low level	Low level

Northern Territory citrus properties

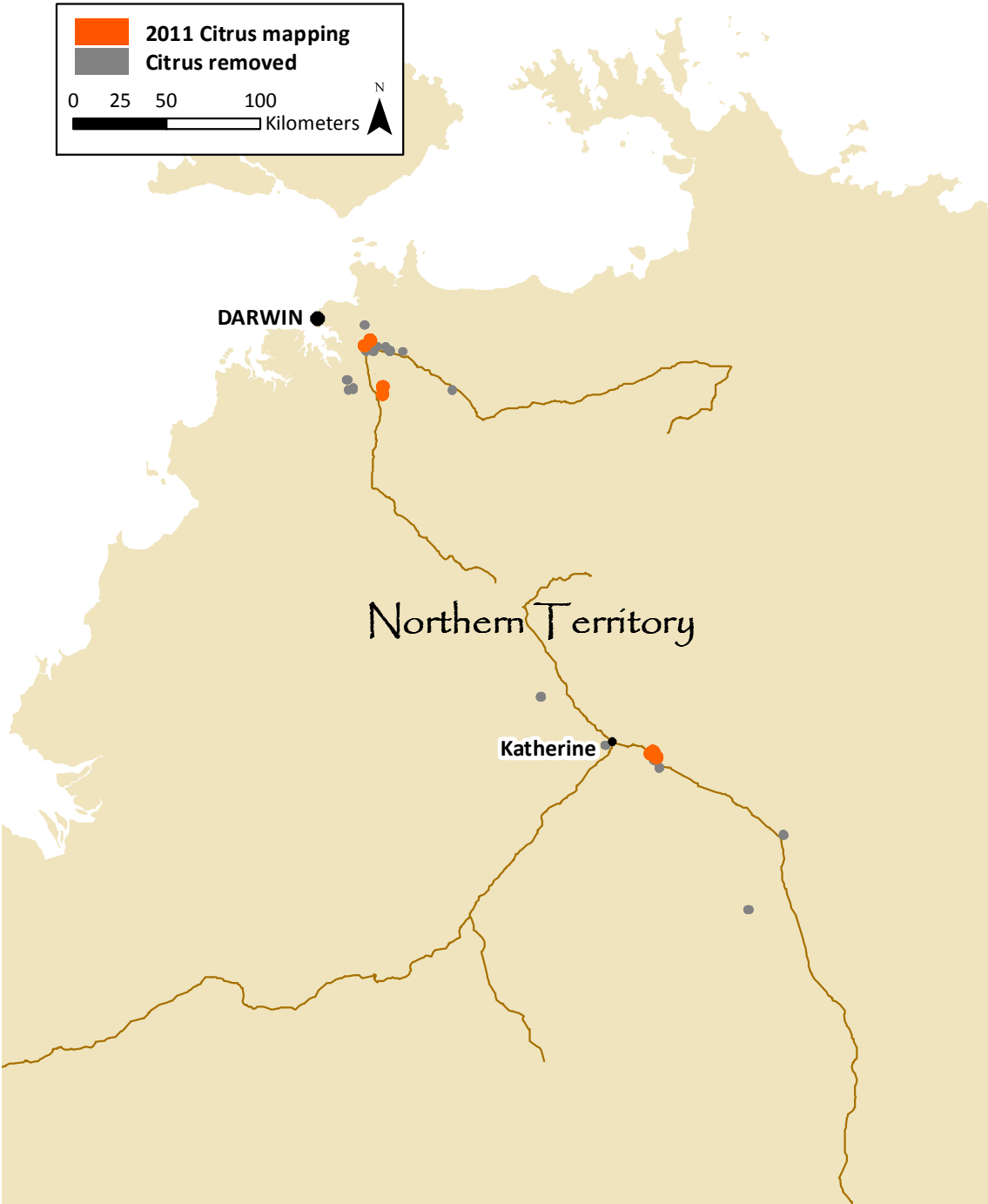
The number of citrus growers declined by 76% (22 growers) between 2003 and 2011, and the average property size increased from 8.0 to 19.6 hectares of citrus as shown in Table 30.

Table 30 – Northern Territory citrus properties

Property size (citrus area)	Number of properties			Change 2003 to 2011	
	2003	2008	2011	properties	% of 2003
< 10 ha	23	11	4	-19	-63%
10 to 20 ha	3	1	0	-3	-10%
20 to 40 ha	3	2	2	-1	-3%
> 40 ha	1	2	1	0	0%
Total properties	30	16	7	-23	-76%
Average property size (ha of citrus)	7.8	12.9	19.6		



Map 8 – Northern Territory citrus map



1.9.2 Northern Territory 2011 citrus varieties

CATEGORY		VARIETY	2011 HECTARES			
			Bearing	Non Bearing	Total	
Grapefruit	red & pink flesh	Flame	9	0	9	6%
		Ray Ruby	2	0	2	2%
		Rio Red	3	0	3	2%
		Star Ruby	20	0	20	15%
Lemon		<i>unspecified</i>	7	0	7	5%
		Eureka	25	43	68	49%
		Lisbon	22	0	22	16%
Lime		Tahitian	4	2	6	5%
Mandarin		<i>unspecified</i>	0	<1	<1	0%
Pummelo			0	<1	<1	0%
TOTAL			92	45	137	100%

Note: Bearing trees were planted six or more years ago or reworked three or more years ago.

1.9.3 Northern Territory change since 2003

CATEGORY	VARIETY		2011 Hectare	Change since 2003	2011 Trees	Change since 2003
Grapefruit		unspecified	0	0	0	-110
	red & pink flesh	Flame	9	-16	3,120	-5,566
		Henderson	0	-1	0	-112
		Ray Ruby	2	-2	750	-612
		Rio Red	3	-35	1,220	-12,119
		Ruby Red	0	-6	0	-2,550
		Star Ruby	20	0	7,345	-200
Lemon	unspecified	7	-7	3,000	-2,020	
	Eureka	68	+41	21,105	+12,284	
	Fino	0	-1	0	-406	
	Lemonade	0	-4	0	-1,303	
	Lisbon	22	-24	8,160	-8,089	
	Meyer	0	-3	0	-1,269	
Lime	Kaffir	0	-1	0	-458	
	Tahitian	6	-20	2,596	-7,098	
	West Indian	0	-1	0	-410	
Mandarin	unspecified	<1	0	250	+250	
	early season	Fremont*	0	0	0	0
	late season	Emperor	0	0	0	-52
		Murcott	0	-1	0	-320
		Mandarin total		<1	-1	250
Pummelo	unspecified	0	-14	0	-5,066	
	Pomelit	<1	0	200	+200	
TOTAL			137	-95	47,746	-35,026

*Note: 880 Fremont trees were planted & removed between 2003 and 2011

References

Part 4 Details of subcategories and varieties for InfoCitrus 2011 (June)_final.doc

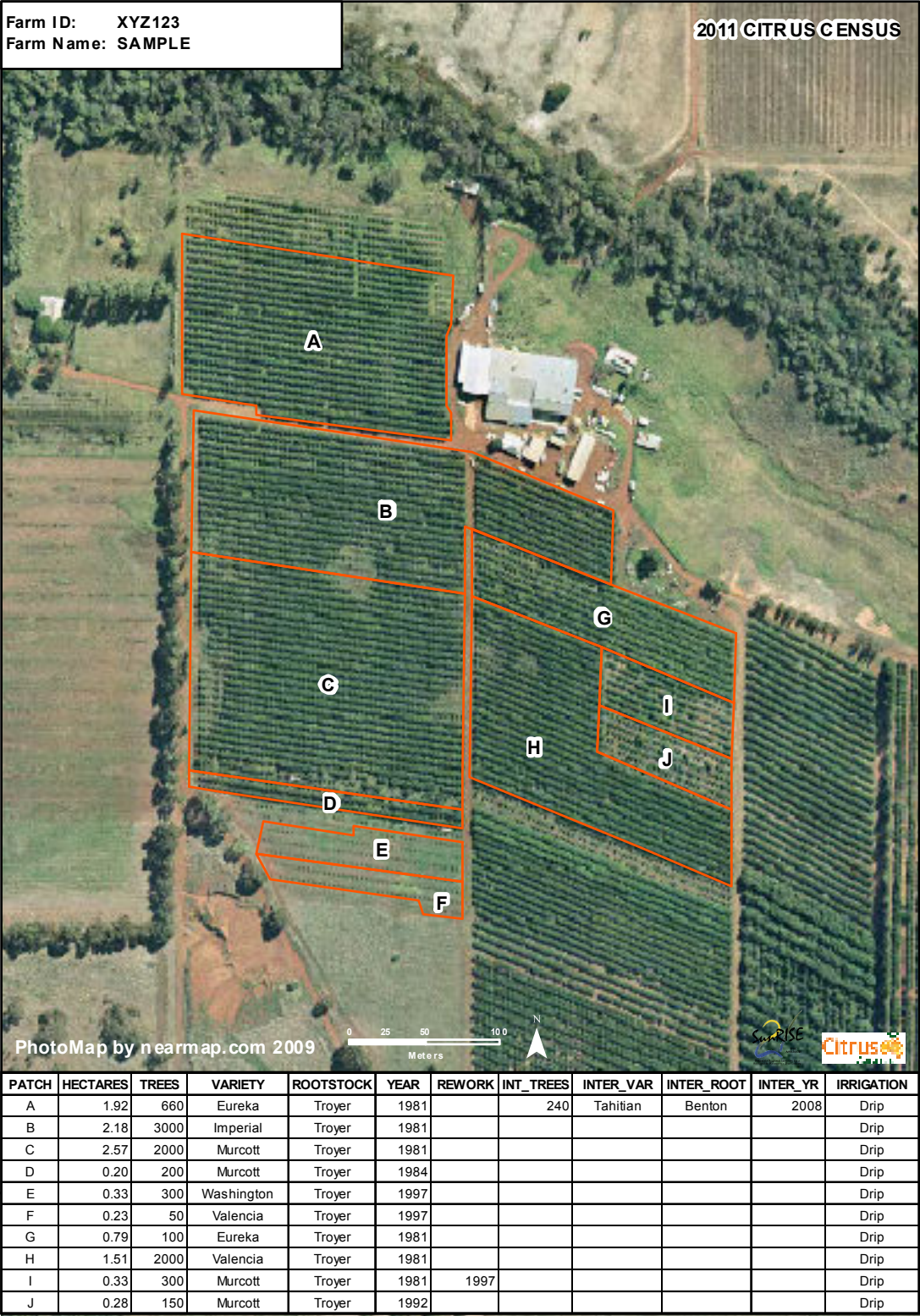
Citrus Pages www.users.kymp.net/citruspages

College of Natural and Agricultural Sciences, Citrus Variety Collection,
www.citrusvariety.ucr.edu/citrus

Final Report CT02033 Utilising new technologies to improve national citrus crop forecasting –
Stage 2: National Plantings Database, SunRISE 21 Inc., July 2006.

National Citrus Plantings Database Management - 2008 Citrus Report, CT07055, December
2008.

Appendix A – Sample property crop plan



Appendix B – Standard crop database fields

Field name	Field type	Record*	Description
Ortho	string	assigned	Shows status of the mapping with respect to the date of imagery used. This field can be used to check progress when updating the mapping to an updated image base.
Source	string	assigned	Source for collection of the data eg grower or via another data source such as an irrigation authority, or details mapped from orthophoto
Survey	string	assigned	Year that the grower was last surveyed – otherwise NS for Not Surveyed
Location	string	assigned	Property location / irrigation district
Block_id or Farm_id	string	assigned	Unique Block or Farm reference. Must be first 4 letters of 'Location'+3 numbers eg.GRIF001
Citrus_id	string	assigned	Unique citrus grower registration number
Property	string	collected	Owner or Property name Must be surname then initials eg SMITH B
Patch	string	assigned	Patch ID – A to Z then ZA to ZZ then ZZA to ZZZ etc. (unless otherwise specified by grower)
Area_ha	Numeric 2 dec places	calculated	Area of crop patch in hectares
Row_m	Numeric 2 dec places	collected	Row & Planting spacing in metres (can be collected in feet and then converted to metres) Only necessary if 'Trees' is not known
Plant_m	Numeric 2 dec places	collected	
Trees	Numeric 0 dec places	collected	Number of trees – preferably collected from grower; else count from ortho; else = $[\text{Area\_ha}] * 10,000 / [\text{Row\_m}] / [\text{Plant\_m}]$
Type	string	assigned	Grape, Citrus, Field crop, Vegetable, Vacant (i.e. in redevelopment), Fruit Tree, Nut Tree etc.
Category	string	assigned	Crop category e.g. Navel
Variety	string	collected	Crop variety name e.g. Barnfield
Rootstock	string	collected	Crop rootstock name or 'Own Roots'
Year	Numeric 0 dec places	collected	Year of planting (of rootstock) eg 1978
Rework	Numeric 0 dec places	collected	Year reworked or top-worked eg 2000
Inter_yr	Numeric 0 dec places	collected	Year of inter-planting
Int_type	string	assigned	Inter-planted crop type
Int_catego	string	assigned	Inter-planted crop category
Inter_var	string	collected	Inter-planted crop variety
Inter_root	string	collected	Inter-planted crop rootstock
Int_trees	Numeric 0 dec places	collected	Number of interplant trees
Irrigation	string	collected	Irrigation method eg lowlevel, drip, furrow, overhead

*Collected = Collected from Grower by Survey Field Officer *Assigned = Assigned or allocated by the Project Manager or GIS Officer

Property database fields

Collected and maintained for Regional purposes only.

Field Name	Field Type	Description
Block_id or Farm_id	string	Block/Farm reference Used as link between Crop and Property databases
Property	string	Property or Owner name
Company	string	Company Name
Trading	string	Trading Name
Contact	string	Contact name for property
Phone	string	Phone number for contact person
Fax	string	Fax number for contact person
Mobile	string	Mobile number for contact person
Email	string	Email address for contact person
Title	string	Name for mail out
Postal	string	Postal address for contact person
Town	string	
Postcode	string	
State	string	VIC, NSW, QLD, NT, WA, SA
Address	string	Address of Fruit Block
Notes	string	
Citrus_id	string	Grower registration number – if applicable

Appendix C – National 2011 citrus varieties list

CATEGORY		VARIETY	2011 HECTARES			
			Bearing*	Non-bearing	Total	
Citrus		<i>not surveyed</i>	1,264	146	1,410	5%
Citron	Citron	Buddha's Hand	<1	0	<1	0%
Cumquat		Cumquat	0	1	1	0%
Grapefruit	Grapefruit white flesh	<i>unspecified grapefruit</i>	122	0	122	0%
		Marsh	108	0	108	0%
		Oroblanco	0	0	0	0%
		Thompson	2	0	2	0%
		Poorman (NZ grapefruit)	<1	0	<1	0%
	Grapefruit pink & red flesh	Flame	107	1	108	0%
		Henderson	1	0	1	0%
		Ray Ruby	12	0	12	0%
		Rio Red (Rio Star)	113	5	118	0%
		Ruby(Red,Pink),Redblush	23	1	25	0%
		Star Ruby	88	7	94	0%
		Thompson (Eagle)	37	0	37	0%
Lemon		<i>unspecified lemon</i>	104	19	124	0%
		Eureka	480	136	615	2%
		Eureka Seedless	3	43	46	0%
		Fino	7	0	7	0%
		Francovielo	1	0	1	0%
		Lambert Eureka	0	0	0	0%
		Lemonade	3	0	3	0%
		Limoniera	2	0	2	0%
		Lisbon	210	12	222	1%
		Meyer	2	0	2	0%
		Verna	8	0	8	0%
		Villa Franca	1	0	1	0%
		Yen Ben	1	0	1	0%
Lime		<i>unspecified lime</i>	5	34	39	0%
		Blood	<1	0	<1	0%
		Desert	0	0	0	0%
		Finger	1	0	1	0%
		Kaffir	<1	0	<1	0%
		Outback	1	0	1	0%
		Sunrise	0	0	0	0%
		Tahitian (Persian)	70	40	110	0%
		West Indian (Mexican)	2	0	2	0%
Mandarin		<i>unspecified mandarin</i>	48	4	52	0%
		Tangerine	1	0	1	0%
	Mandarin early season	Amigo	8	0	8	0%
		Caffin Clementine	0	1	1	0%
		Clementine	49	3	52	0%
		Fallglo	12	0	12	0%
		Feutrell	1	0	1	0%
		Fina Clementine	0	0	0	0%
		Fremont	28	1	29	0%
		Goldup	1	37	38	0%
		Imperial	1,401	363	1,764	6%
		Marisol Clementine	1	0	1	0%
		Miho Wase Satsuma	3	1	4	0%

National 2011 citrus varieties list continued

CATEGORY	VARIETY	2011 HECTARES			
		Bearing*	Non-bearing	Total	
Mandarin Early Season <i>continued</i>	Nova (Suntina)	56	0	56	0%
	Nules Clementine	63	18	81	0%
	Okitsu Wase Satsuma	8	0	8	0%
	<i>Satsuma unspecified</i>	23	0	23	0%
	Silverhill Satsuma	0	0	0	0%
Mandarin early season total		1,653	424	2,077	7%
Mandarin mid season	Afourer (Nadorcott)	306	247	553	2%
	Avana (Aperino, Tardivo)	10	28	38	0%
	Daisy	96	28	124	0%
	Dancy Tangerine	2	0	2	0%
	Darling	1	0	1	0%
	Dekopon	2	3	5	0%
	Ellendale	136	0	137	0%
	Ellenor	7	0	7	0%
	Empress	43	3	46	0%
	Hickson	169	23	192	1%
	GoldenNugget	0	4	4	0%
	Monarch	3	0	3	0%
	Nectar	0	6	6	0%
	Oroval Clementine	<1	0	<1	0%
	Page	0	0	0	0%
	Parker	0	0	0	0%
	Success	9	0	9	0%
	Sunburst	20	0	20	0%
	Taylor Lee	59	0	59	0%
	TDE Mandarin	0	<1	<1	0%
Mandarin mid season total		864	342	1,206	4%
Mandarin late season	Alkantara	0	1	1	0%
	Emperor	4	0	4	0%
	Hansen	<1	0	<1	0%
	Kara (Carra)	5	0	6	0%
	Murcott	883	318	1,201	4%
	Murcott Honey	3	24	27	0%
	Murcott LS	13	248	261	1%
	Mystique	14	13	28	0%
	Sunset	0	0	0	0%
	Topaz, Ortanique	41	3	44	0%
Mandarin late season total		964	608	1,572	6%
Mandarin total		3,350	1,379	4,909	17%
Navel	<i>unspecified navel</i>	240	0	240	1%
	<i>unspecified early navel</i>	5	0	5	0%
	Atwood	43	21	64	0%
	Biggs Leng	2	0	2	0%
	Early Bird	<1	0	<1	0%
	Fisher	38	7	45	0%
	Fuko Mozonau	5	0	5	0%
	Fukumoto	17	1	18	0%
	Fulwood	2	0	2	0%
	Golden Nugget	1	0	1	0%

National 2011 citrus varieties list continued

CATEGORY		VARIETY	2011 HECTARES			
			Bearing*	Non-bearing	Total	
Navel	Navel early season <i>continued</i>	Hammet	1	0	1	0%
		Leng	697	28	724	3%
		Lloyd Leng	1	0	1	0%
		M7 Navel	8	67	75	0%
		Navelencia	0	0	0	0%
		Navelina(Italian,Spanish)	993	40	1,033	4%
		Newhall (Naveline)	41	42	83	0%
		Nucellar Leng	27	0	27	0%
		Pasin	23	3	27	0%
		Riverside	1	1	2	0%
		Rosey Red	4	3	7	0%
		Ryan	78	0	78	0%
		Thomson	61	2	63	0%
		Whitely	6	0	6	0%
		Winter Navel	6	0	6	0%
Navel early season total		2,059	215	2,274	8%	
Navel mid season	Bellamy	1	0	1	0%	
	Cara Cara (Red Navel)	137	43	179	1%	
	Cellaline	<1	0	<1	0%	
	Follett	<1	0	<1	0%	
	Hockney	5	0	5	0%	
	Langdon	10	0	10	0%	
	Navelate (Tardia)	2	0	2	0%	
	Palmer	5	0	5	0%	
	Salisbury	2	0	2	0%	
	Sun Smooth	0	0	0	0%	
	Washington	3,294	159	3,453	12%	
Navel mid season total		3,456	202	3,657	13%	
Navel late season	<i>unspecified late navel</i>	333	0	333	1%	
	Albanese	<1	0	<1	0%	
	Autumn Gold (Pollock)	86	4	89	0%	
	Barnfield	395	6	401	1%	
	Chislett	487	65	552	2%	
	Christensen	3	0	3	0%	
	Christmas	<1	0	<1	0%	
	Clark (Doug Clarke)	31	0	31	0%	
	Edwards	2	0	2	0%	
	Fairlane	0	0	0	0%	
	Garraway	0	0	0	0%	
	Honey Gold	2	0	2	0%	
	Hutton	39	0	39	0%	
	Late Lane	2,856	210	3,067	11%	
	Murray Gold	2	0	2	0%	
	Pillar	0	0	0	0%	
	Powell	200	1	201	1%	
	Ravens Choice	5	0	5	0%	
	Rohde	43	13	56	0%	
	Scopelliti	6	0	6	0%	
	Summer Gold (Marrows)	100	1	100	0%	
	Taylor	1	0	1	0%	
	Toc	12	0	12	0%	
	Toomey	3	0	3	0%	
	Wiffen	15	0	15	0%	
	Wilson	67	0	67	0%	
Navel late season total		4,688	301	4,988	18%	
Navel Total		10,442	717	11,159	40%	

National 2011 citrus varieties list *continued*

CATEGORY		VARIETY	2011 HECTARES			
			Bearing*	Non-bearing	Total	
Orange	Blood	<i>unspecified</i>	21	3	24	0%
Misc.	Orange	Arnold (Moro)	45	5	50	0%
		Maltese	<1	0	<1	0%
		Ruby	1	0	1	0%
		Tarocco	2	0	3	0%
	Sweet	Acidless (Non Acid)	<1	<1	<1	0%
	Orange	Common Orange	2	0	2	0%
		Hamlin	156	175	330	1%
		Honey Ball	3	9	12	0%
		Joppa	5	0	5	0%
		Lima acidless	3	0	3	0%
		Parramatta	0	0	0	0%
		Parson Brown	29	0	29	0%
		Pera (Bianchi, Limeria)	19	0	19	0%
		Pineapple	35	39	74	0%
		Salustiana	255	170	425	2%
		Seleta (Siletta)	0	0	0	0%
	Sour	Seville	26	0	26	0%
		Smooth Seville	1	0	1	0%
Pummelo		<i>Pummelo unspecified</i>	3	0	3	0%
		Pomelit (Pomelette)	0	0	0	0%
Tangelo		<i>unspecified Tangelo</i>	82	1	83	0%
		Minneola	193	3	196	1%
		Orlando	0	0	0	0%
		Seminole	2	0	2	0%
Valencia		Appleby T2	1	0	1	0%
		Ben Yenda	1	32	33	0%
		Berri	6	0	6	0%
		Casey	8	0	8	0%
		Dwarf	7	0	7	0%
		Keenan	0	33	33	0%
		Lord Howe	6	0	6	0%
		Newton	36	0	36	0%
		Owen	0	0	0	0%
		Pecta	2	0	2	0%
		Smith Red	10	0	10	0%
		Valencia	7,138	32	7,171	25%
		Valencia Late	23	0	23	0%
	Valencia	Delta	45	1	46	0%
	Seedless	Early Glow	0	0	0	0%
		McMahon	14	55	70	0%
		Midknight	40	37	77	0%
		Valencia Seedless	97	14	111	0%
TOTAL			25,067	3,150	28,217	100%

*Bearing trees were planted six or more years ago (i.e. planted in 2002 or earlier) or were reworked three or more years ago (i.e. reworked in 2005 or earlier).

Note: 2011 figures for Riverland are unavailable and 2008 figures have been used for 2011
2011 figures for Riverina have only been updated for 50% of growers since 2008 and
bearing/non-bearing figures were unavailable for Riverina

Appendix D – National citrus varieties change 2003 to 2011

CATEGORY		VARIETY	2011 hectare	Change since 2003	2011 trees	Change since 2003
Citrus		<i>not surveyed</i>	1,410	+481	657,274	+274,692
Citron		Buddha's Hand	0	0	47	+47
Cumquat		Cumquat	1	+1	360	+360
Grapefruit	Grapefruit white flesh	<i>unspecified grapefruit</i>	122	-35	50,254	-15,425
		Marsh	108	-95	43,835	-42,728
		Melogold	0	0	0	0
		Oroblanco	2	-7	822	-4,083
		Poorman (NZ grapefruit)	0	0	50	0
	Grapefruit pink & red flesh	Flame	108	+32	41,965	+13,874
		Henderson	1	-1	400	-450
		Ray Ruby	12	-5	3,195	-1,166
		Rio Red (Rio Star)	118	+16	40,028	+1,708
		Ruby(Red,Pink),Redblush	25	-5	10,065	-1,355
		Star Ruby	94	+5	42,188	+3,933
		Thompson (Eagle)	37	+21	17,859	+10,678
	Lemon	<i>unspecified lemon</i>	124	-38	51,244	-13,758
		Eureka	615	-189	247,051	-115,593
		Eureka Seedless	46	+46	21,834	+21,834
		Fino	7	-2	2,366	-875
		Francovielo	1	-6	541	-2,059
		Lambert Eureka	0	0	0	-140
		Lemonade	3	-4	1,837	-1,444
		Limoniera	2	0	890	0
		Lisbon	222	-93	77,317	-28,833
		Meyer	2	-9	690	-3,962
		Verna	8	-6	2,907	-2,848
		Villa Franca	1	0	231	+135
		Yen Ben	1	0	463	0
Lime		<i>unspecified lime</i>	39	+36	18,661	+16,945
		Blood	0	-4	44	-1,907
		Desert	0	-1	0	-696
		Finger	1	+1	442	+392
		Kaffir	0	-2	252	-558
		Outback	1	-1	116	-583
		Sunrise	0	-2	0	-1,203
		Tahitian (Persian)	110	-33	41,506	-19,101
		West Indian (Mexican)	2	-1	795	-535
Mandarin		<i>unspecified mandarin</i>	52	+30	18,890	+9,375
		Tangerine	1	0	407	0
	Mandarin early season	Amigo	8	-3	3,467	-1,840
		Caffin Clementine	1	+1	945	+945
		Clementine	52	-7	32,472	-2,866
		Fallglo	12	-10	8,638	-9,372
		Feutrell	1	0	156	-44
		Fina Clementine	0	0	0	-132
		Fremont	29	-24	14,663	-11,484
		Goldup	38	+38	15,352	+15,352
		Imperial	1,764	-79	793,009	-16,757
		Marisol Clementine	1	-1	540	-276
		Miho Wase Satsuma	4	0	2,530	-310

Mandarin	Mandarin	Nova (Suntina)	56	-65	27,263	-26,745
	early	Nules Clementine	81	+16	53,023	+9,332
	season	Okitsu Wase Satsuma	8	-1	6,693	-198
	<i>continued</i>	<i>Satsuma unspecified</i>	23	0	19,879	-623
		Silverhill Satsuma	0	0	80	-132
Mandarin early season total			2,077	-136	978,710	-45,150
Mandarin		Afourer (Nadorcott)	553	+521	347,031	+323,784
mid		Avana (Aperino,Tardivo)	38	+38	15,502	+15,408
season		Daisy	124	+53	66,146	+32,362
		Dancy Tangerine	2	-4	859	-1,044
		Darling	1	0	260	0
		Dekopon	5	+5	2,700	+2,700
		Ellendale	137	-277	57,750	-92,092
		Ellenor	7	-34	3,787	-11,042
		Empress	46	+9	15,165	+2,750
		Hickson	192	-85	83,103	-25,977
		GoldenNugget	4	+4	1,849	+1,849
		Monarch	3	0	1,094	0
		Nectar	6	+6	731	+731
		Oroval Clementine	0	0	300	0
		Page	0	-5	0	-1,243
		Parker	0	0	0	-40
		Success	9	-12	3,457	-4,273
		Sunburst	20	-35	11,730	-17,764
		Taylor Lee	59	-71	27,129	-27,214
		TDE Mandarin	0	0	400	+400
Mandarin mid season total			1,206	113	638,993	199,296
Mandarin		Alkantara	1	+1	171	+171
late		Emperor	4	-3	1,915	-1,115
season		Hansen	0	-1	51	-533
		Kara (Carra)	6	-14	2,081	-6,733
		Murcott	1,201	-518	549,996	-242,920
		Murcott Honey	27	+25	16,316	+15,346
		Murcott LS	261	+261	116,203	+116,203
		Mystique	28	+16	17,129	+10,409
		Sunset	0	0	0	-100
		Topaz, Ortanique	44	+13	23,803	+8,597
Mandarin late season total			1,572	-220	727,665	-100,675
Mandarin Total			4,909	-213	2,364,665	62,846
Navel		<i>unspecified navel</i>	240	-98	109,724	-40,958
Navel		<i>unspecified early navel</i>	5	+1	2,469	+427
early		Atwood	64	+44	35,197	+23,389
season		Biggs Leng	2	0	664	0
		Early Bird	0	0	98	+98
		Fisher	45	+12	22,572	+3,256
		Fuko Mozonau	5	+5	4,490	+4,490
		Fukumoto	18	-3	11,696	+2,048
		Fulwood	2	0	1,342	0
		Golden Nugget	1	0	418	0
		Hammet	1	-1	600	-440
		Leng	724	-266	287,436	-112,466
		Lloyd Leng	1	-1	482	-288
		M7 Navel	75	+75	45,774	+45,774
		Navelencia	0	0	0	0

National citrus varieties change 2003 to 2011 *continued*

National Citrus Varieties Change 2003 to 2011 continued						
CATEGORY		VARIETY	2011 hectare	Change since 2003	2011 trees	Change since 2003
Navel	Navel	Navelina(Italian,Spanish)	1,033	-226	528,251	-122,519
	early	Newhall (Naveline)	83	+29	50,985	+16,375
	season	Nucellar Leng	27	+3	14,454	+3,028
	continued	Pasin	27	+1	14,875	+607
		Riverside	2	+1	653	+314
		Rosey Red	7	+4	3,733	+2,373
		Ryan	78	+8	34,351	+3,454
		Thomson	63	-49	24,330	-20,873
		Whitely	6	-1	3,212	-440
		Winter Navel	6	0	1,717	-121
	Navel early season total		2,274	-365	1,089,799	-151,515
	Navel	Bellamy	1	0	207	-54
	mid	Cara Cara (Red Navel)	179	+112	90,435	+59,311
	season	Cellaline	0	0	40	0
		Follett	0	0	120	0
		Hockney	5	+1	2,457	+488
		Langdon	10	+2	3,895	+696
		Navelate (Tardia)	2	-1	543	-954
		Palmer	5	+1	3,205	+841
		Salisbury	2	0	648	0
		Sun Smooth	0	0	0	0
		Washington	3,453	-618	1,429,446	-164,150
Navel mid season total		3,657	-504	1,530,996	-103,822	
Navel	unspecified late navel	333	+12	132,607	+13,673	
late	Albanese	0	0	96	0	
season	Autumn Gold (PollockL.)	89	+1	49,448	+1,489	
	Barnfield	401	+8	179,044	+2,603	
	Chislett	552	+153	279,692	+80,209	
	Christensen	3	0	1,356	0	
	Christmas	0	0	200	0	
	Clark (Doug Clarke)	31	-1	10,409	+489	
	Edwards	2	0	1,036	0	
	Fairlane	0	0	0	0	
	Garraway	0	0	0	-161	
	Honey Gold	2	0	1,329	0	
	Hutton	39	+9	18,264	+4,235	
	Late Lane	3,067	+130	1,384,845	+92,937	
	Murray Gold	2	0	1,167	-75	
	Pillar	0	0	0	-147	
	Powell	201	+19	88,268	+8,544	
	Ravens Choice	5	+3	1,601	+729	
	Rohde	56	+9	25,323	+4,736	
	Scopelliti	6	-1	2,976	-866	
	Summer Gold (Marrows)	100	-38	59,001	-19,612	
	Taylor	1	0	356	0	
	Toc	12	0	4,289	0	
	Toomey	3	0	1,423	0	
	Wiffen	15	+1	6,984	+106	
	Wilson	67	-12	29,473	-5,811	
Navel late season total		4,988	291	2,279,188	183,078	
Navel Total		11,195	-675	5,009,707	-113,217	

National citrus varieties change 2003 to 2011 *continued*

CATEGORY		VARIETY	2011 hectare	Change since 2003	2011 trees	Change since 2003
Orange	Blood	<i>unspecified</i>	24	-6	14,469	-1,713
Misc.	Orange	Arnold (Moro)	50	+35	36,264	+28,680
		Maltese	0	0	31	-124
		Ruby	1	0	498	0
		Tarocco	3	+3	2,272	+2,272
	Sweet	Acidless (Non Acid)	0	0	230	+110
	Orange	Common Orange	2	-4	781	-3,125
		Hamlin	330	+240	222,286	+162,712
		Honey Ball	12	+12	7,443	+7,443
		Joppa	5	-3	1,576	-1,039
		Lima acidless	3	0	3,175	+1,450
		Parramatta	0	-1	0	-333
		Parson Brown	29	+20	19,761	+11,108
		Pera (Bianchi, Limeria)	19	0	6,169	+110
		Pineapple	74	+73	46,756	+46,051
		Salustiana	425	+389	251,464	+218,391
		Seleta (Siletta)	0	-2	0	-1,069
	Sour	Seville	26	-11	9,105	-4,334
		Smooth Seville	1	0	959	0
Pummelo		<i>Pummelo unspecified</i>	3	-14	1,446	-4,346
		Pomelit (Pomelette)	0	0	200	+200
Tangelo		<i>unspecified Tangelo</i>	83	-1	43,178	+826
		Minneola	196	-46	98,680	-24,167
		Orlando	0	-3	104	-1,240
		Seminole	2	0	848	-827
Valencia		Appleby T2	1	-2	463	-330
		Ben Yenda	33	+32	18,775	+18,228
		Berri	6	+2	4,150	+2,230
		Casey	8	-13	3,082	-5,580
		Dwarf	7	0	8,587	0
		Keenan	33	+31	18,862	+17,914
		Lord Howe	6	+3	1,825	+1,024
		Newton	36	-40	14,858	-21,619
		Owen	0	0	53	0
		Pecta	2	0	544	0
		Smith Red	10	-2	5,275	-561
		Valencia	7,171	-1,673	2,729,308	-570,742
		Valencia Late	23	-57	6,591	-16,787
	Valencia	Delta	46	+29	22,688	+13,692
	Seedless	Early Glow	0	0	0	0
		McMahon	70	+65	50,321	+47,795
		Midnight	77	+39	43,826	+27,829
		Valencia Seedless	111	+23	41,402	+10,291
TOTAL			28,217	-1,668	12,490,205	-4,653

Note: 2011 figures for Riverland are unavailable and 2008 figures have been used for 2011
2011 figures for Riverina have only been updated for 50% of growers since 2008

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National citrus crop forecast

Navels

Navel volumes are expected to be up 12% from 2012, although down almost 20% on the record year of 2009. Climatic conditions have been mild and overall quality is expected to be good.

Fruit size will return to average and a large volume of fruit will be in the preferred size range of 72-88 counts. An increase in volume of late season navels in South Australia is attributed to large plantings in the mid to late 2000s having now reached full production. In contrast, late navel plantings in other regions were harvested very late in the 2012 season which reduced flowering and subsequently yields in 2013 will be lighter.

Valencia

Heavy hedging and late hanging of crops have reduced flowering, which is expected to have a downward impact on Valencia volumes, particularly in the Riverina region. Most regions predict that the 2012/13 Valencia crop will be completely harvested before the common orange and 2013/14 Valencia harvest commences.

Common oranges

The increase in volume of common oranges for juice processing as recent plantings reach full production further explains the reduced intake of Washington navel off-run in the mid-season. These varieties are preferred by processors for their juice content and processing attributes.

Mandarins

A slight increase in the national forecast for mandarins is predicted despite the impact of the Australia Day weekend floods through Queensland. Minor skin blemishes are expected to increase the percentage of second grade fruit from Queensland as growers continue to feel the impact of the floods.

The 2013 season is predicted to be the first in which a greater volume of mandarins will come from the southern regions of Australia than Queensland, as recently planted hectares of Afourer approach full production. Combined production from the Sunraysia and Riverland regions is predicted to reach 53,000 tonnes, compared to 46,000 tonnes from Queensland.

The increased mandarin volume in 2013 follows the trend of rising consumption of easy peeler citrus on the domestic market and in other markets across the world.

2013 Crop Forecast								
Variety	Sunraysia*	Mid Murray	Riverland	Riverina	NSW other	Queensland	Western Australia	Total
Navel	68,000	3,700	100,000	50,000	-	1,800	6,000	229,500
Valencia	28,000	6,000	55,000	110,000	-	500	3,000	202,500
Common Orange	-	-	-	20,000	13,000	-	-	33,000
Mandarin	25,000	-	28,000	2,000	-	46,000	3,000	104,000
Grapefruit	1,500	3,600	3,000	1,000	-	500	1,500	11,100
Tangelo	1,500	-	5,000	-	-	-	-	6,500
Lemon	1,500	400	5,000	1,000	1,000	10,000	1,000	19,900
Lime	800	-	800	400	800	3,200	400	6,400
Total	126,300	13,700	196,800	184,400	14,800	62,000	14,900	612,900
*Citrus Australia acknowledges the Sunraysia data incorporates Murray Valley Board estimates								

Major citrus categories, 000 tonnes			
Year	Navel	Valencia*	Mandarin
2007	236	215	103
2008	190	195	108
2009	270	225	107
2010	177	128	80
2011	250	210	110
2012	205	210	100
2013 est	229	235	104
Note: 2013 estimate includes growing regions previously not included. * 2012 and 2013 include common oranges			



**Australian Government Department of
Agriculture, Fisheries and Forestry**

**Horticulture: review of export efficiency
powers draft report by ABARES**

Submission by Citrus Australia Ltd

Judith Damiani

CEO

15 August 2012

Citrus Australia Ltd

Citrus Australia is the national peak industry body for the Australian citrus growing industry. There are approximately 2,000 citrus growers based in every mainland state and the Northern Territory, but concentrated in the Murray Darling Basin regions of SA, VIC, NSW; and the Central Burnett region of QLD.

The Australian citrus industry is one of the largest fresh fruit industries in Australia, and certainly the largest fresh fruit exporter with an annual average export volume of 170,000 tonnes and a value of \$190 million. Citrus is also one of the largest fresh import categories in Australia, with annual volume of around 23,000 tonnes valued at \$33 million. The Australian citrus industry produces only around 1% of the global citrus production and competes directly in export markets with lower cost southern hemisphere citrus exporting countries such as South Africa, Chile and Peru.

Industry consultation

Citrus Australia, in anticipation of the DAFF review of export regulation powers, commenced industry consultation early in 2011. The following processes were utilised:

- Commissioning of a *US situational and value chain analysis*¹
- Presentation titled “Coordinated Marketing” and break-out group discussion at the National Export Forum held on 24 February 2011 in Melbourne (80 industry attendees)
- In conjunction with Horticulture Australia Ltd (HAL) facilitated a meeting of key stakeholders involved with marketing arrangements into China and USA on 6 May 2011 in Melbourne.
- Required agenda item at each National Export Committee meeting (advisory committee to the Citrus Australia Board)
- 2011 USA post-season review meetings/presentation by DNE: 4 December (SA); 5 December (VIC) and 6 December 2011 (NSW)
- National Export Forum held on 7-8 March 2012 (100 industry attendees)
- Citrus Australia grower member feedback July/August 2012
- Citrus Australia Board meeting 13 August 2012

Citrus Australia believes the consultation process has been extensive and lengthy.

¹ *Situational and Value Chain Analysis on the Australian Citrus to USA Marketing Program*, prepared by CDI Pinnacle Management for Citrus Australia, 3 November 2011 Commercial in Confidence

The citrus industry continues to have strong divergent views on export regulations particularly the single importer arrangements into the US.

Though the split is finely balanced by grower numbers, those with a larger investment in the industry (number of hectares) continue to favour change.

The US market remains a critically important market for Australian citrus, despite the reduced volumes in recent years. A concerted effort is required to grow market share and maintain good returns to high performing growers.

The Chinese market remains a critically important potential market for Australian citrus. A concerted effort is required to improve quarantine access and develop the premium segment of this growing market.

Growers invest significantly into market access and development programs and justifiably deserve to have their returns maximised.

Citrus Australia believes that if the current arrangements are immediately discontinued in the current climate as recommended in the draft report then the risk for creating a negative impact to grower returns are increased due to unmanaged competition.

The current climate encompasses:

- 20 years of export regulation into the USA with a single importer; for which in most years has been the highest returning market for Class 1 fruit.
- Record high exchange rates, assumed by ABARES to only decrease gradually from an average of US104 cents in 2011-12 to US95 cents in 2016-17.
- Pressure on export resulting in more oranges sold on the domestic market already squeezed by a retail duopoly, resulting in unsustainable grower returns.
- Increasing input costs for growers, including increases due to the Australian Government's new horticulture export fees and charges and carbon tax imposed on 1 July 2012; confirming Australia's position as the highest cost citrus producer in the world.
- Major industry organisational changes including the winding up of state citrus statutory boards (currently underway in Riverina, NSW and SA)

- The long lead time for industry varietal adjustment (it takes an average of four to six years for a young citrus tree to bear commercially)

A transition period of two years is proposed for the Australian citrus industry to adjust to any changes to the current arrangements; and manage the increased competition to maximise grower returns:

The transition plan could involve:

- Retention of the Export Efficiency Powers by DAFF, held in reserve.
- The opportunity for Citrus Australia to enhance InfoCitrus with voluntary real-time weekly export data by market provided by citrus packer/exporters.
- The opportunity for industry to discuss and debate the use of alternate export controls such as internal quality standards. Citrus Australia has developed and implemented a voluntary Australian Citrus Quality Standards for the domestic market. The program has been in place for only 15 months and continues to gather momentum. We have planned for the program to assist in building a quality culture in the industry over the next 3 years. The South African citrus industry continues to utilise export controls to regulate minimum standards for export fruit.
- The opportunity to improve protocol access and consumer demand for Australian citrus to China and other targeted Asian markets.
- Citrus Australia to review the effectiveness of its voluntary Australian Citrus to Japan program
- Citrus Australia to facilitate and lead industry discussion and action on the sustainability of its current varietal and volume mix considering increasing international competition; ongoing high exchange rate and the continuing low price domestic retailer strategy.
- Citrus Australia to encourage growers to maintain collaborative export supply chains; and exporters to continue to utilise DNE World Fruit Sales into the US market, as a proven, reliable and effective citrus category manager in the overwhelming US retail sector.
- The facilitation of trade missions to increase the industry's collective knowledge of the individual export markets and trade/consumer preferences particularly in the US.

A review could take place toward the end of the transition period to review industry's adjustment and recommend any final changes to the retention of Export Efficiency Powers.

Summary

The Australian citrus industry has a proven track record for generating valuable export income for regional communities and the Australian economy; and anticipates future opportunities to feed a growing and affluent Asian population.

However the Australian industry is facing:

- Unprecedented cost increases, most recently with the introduction of the Australian Government's new horticultural export fees and charges and carbon tax, and a medium term outlook for a continuing high Australian exchange rate.
- Increased Southern hemisphere competition from low cost producing citrus countries such as South Africa and Chile
- Increased domestic market pressure with the low priced duopoly retail sector.
- Significant restructuring of its industry representative organisations.

The Australian Government should assist the Australian citrus industry adjust to a fully deregulated export market environment; and an increasingly competitive and costly business environment. There are a number of manufacturing industries in Australia which currently enjoy significant Australian Government support.

This can be done in a number of ways:

- Maintaining Export Efficiency Powers in reserve for two years, and reviewing industry's adjustment before completely removing them.

Retaining Export Efficiency Powers in reserve for two years will allow industry time to enhance industry programs to provide more effective information; facilitate industry discussion regarding potential alternate uses of the Powers; encourage export collaboration; gain better access to key export markets; review the effectiveness of current voluntary export programs; and will provide a broad safety net to protect grower returns if required.

- Increasing its commitment to horticultural export market access and maintenance, both in technical and trade areas.

- Speeding up priority market access negotiations through Ministerial and industry trade missions.

Summary of HAL funded projects managed by Citrus Australia for the period 2010-2016 as at 30 June 2013

HAL Contracted Projects		Project Details			Comments	Annual Budget							
Project No	Title	Start Date	End Date	LOP Budget	Notes	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	Project Total
CT09034	National Infocitrus Development Project	1/10/2010	15/06/2013	496,000			197,400	157,400	141,200				496,000
CT09043	Huanglongbing and Citrus Canker Study Tour to USA	1/01/2010	28/02/2010	57,586	Full VC matchable	57,586							57,586
CT09055	Co-ordinating a market development program for the Australian citrus value chain	1/04/2010	30/06/2013	1,457,942	Partial VC		777,216	358,254	322,472				1,457,942
CT10023	Citrus Export Market Access and Maintenance	1/07/2010	30/05/2013	270,000			90,000	90,000	90,000				270,000
CT10024	National Citrus Communications Program	19/10/2010	31/07/2013	1,110,000			355,000	355,000	284,500	115,500			1,110,000
CT10025	Citrus industry biosecurity and incursion management	7/07/2010	30/05/2013	270,000			90,000	90,000	90,000				270,000
CT10027	Citrus Levy Consultation	12/12/2011	25/04/2014	60,000			20,000		20,000	20,000			60,000
CT10043	Citrus market access pests: investigating a new approach	1/12/2011	30/06/2012	30,000				24,000	6,000				30,000
CT10035	Citrus National Plantings Database - Update 2011	20/01/2011	30/09/2011	67,300			48,250	19,050					67,300
CT10042	Situational and value chain analysis on Australian citrus to US marketing program	10/01/2011	29/04/2012	24,750				24,750					24,750
CT10700	Citrus Australia 2010 National Conference	1/10/2010	31/12/2010	96,900	Full VC matchable		96,900						96,900
CT11006	Strategic Agrichemical Review Process (SARP)	1/10/2011	31/01/2012	11,510				11,510					11,510
CT12004	Australian Citrus Quality Standards Program - Stage 2	1/07/2012	1/07/2015	514,923					154,953	180,000	76,985	102,985	514,923
CT12005	Driving citrus exports through improved market access	15/08/2012	30/06/2015	699,103					179,103	270,000	180,000	70,000	699,103
CT11011	Agrichemical residue monitoring program for Australian citrus exports	28/06/2012	30/04/2015	108,000				15,000	5,000	40,000	48,000		108,000
CT11704	Citrus Australia 2011 National Conference	9/01/2011	15/12/2011	99,500	Full VC matchable			99,500					99,500
CT12020	An interim citrus estimates program to develop a national forecast	20/01/2013	30/05/2013	38,711					38,711				38,711
CT12700	12th International Citrus Congress, Valencia, Spain 2013 - Study Tour	15/08/2012	31/01/2013	71,250	Full VC matchable				71,250				71,250
CT12701	Citrus Australia 2012 National Conference	15/08/2012	15/12/2012	99,500	Full VC matchable				99,500				99,500
	TOTALS			5,582,975		57,586	1,674,766	1,244,464	1,502,689	625,500	304,985	172,985	5,582,975
	HAL Partnership/Consultation Agreement with PIB												
CT10910	2010 Citrus Partnership Agreement	1/07/2010	10/08/2011	200,479			200,479						200,479
CT11910	2011 Citrus Partnership Agreement - consultation	1/07/2011	10/08/2012	159,479				159,479					159,479
CT12910	2012 Citrus Partnership Agreement - consultation	1/07/2012	10/08/2013	159,480					159,480				159,480
	TOTALS			519,438			200,479	159,479	159,480				519,438

HUANGLONGBING AND ITS VECTORS

A Pest Specific Contingency Plan for the Citrus and Nursery and Garden Industries

PATHOGENS	
COMMON NAMES	huanglongbing (official common name, meaning ‘yellow shoot disease’), citrus greening (informal common name), likubin or decline (Taiwan), leaf mottling (Philippines), citrus dieback (India), citrus vein-phloem degeneration (Indonesia), citrus greening, yellow branch or blotchy-mottle (South Africa)
SCIENTIFIC NAMES	‘ <i>Candidatus Liberibacter asiaticus</i> ’ (Asiatic form), ‘ <i>Ca. L. africanus</i> ’ (African form) and ‘ <i>Ca. L. americanus</i> ’ (South American form)
SYNONYMS	‘ <i>Ca. Liberobacter asiaticus</i> ’ and ‘ <i>Ca. Liberobacter asiaticum</i> ’ ‘ <i>Ca. Liberobacter africanus</i> ’ and ‘ <i>Ca. Liberobacter africanum</i> ’
ASIATIC VECTOR	
COMMON NAMES	Asiatic citrus psyllid, Asian citrus psyllid, oriental citrus psyllid, citrus psylla
SCIENTIFIC NAME	<i>Diaphorina citri</i> Kuwayama [Hemiptera: Sternorrhyncha: Psylloidea: Psyllidae]
SYNONYMS	<i>Euphalerus citri</i> Crawford
AFRICAN VECTOR	
COMMON NAME	African citrus psyllid, citrus psylla
SCIENTIFIC NAME	<i>Trioza erytrae</i> (del Guercio) [Hemiptera: Sternorrhyncha: Psylloidea: Triozidae]
SYNONYMS	<i>Aleurodes erytrae</i> del Guercio; <i>Trioza citri</i> Laing; <i>Trioza merwei</i> Petty; <i>Spanioza merwei</i> (Petty); <i>Spanioza erythrae</i> (del Guercio); <i>Spanioza erytrae</i> del Guercio

The scientific and technical content of this document is current to the date published and all efforts were made to obtain relevant and published information on the threat. The document will require frequent revision.

Prepared by:
GAC Beattie (University of Western Sydney) & Patricia Barkley (Citrus Australia Ltd.)
through funding from Horticulture Australia Limited citrus levy projects CT02005 & CT07026.

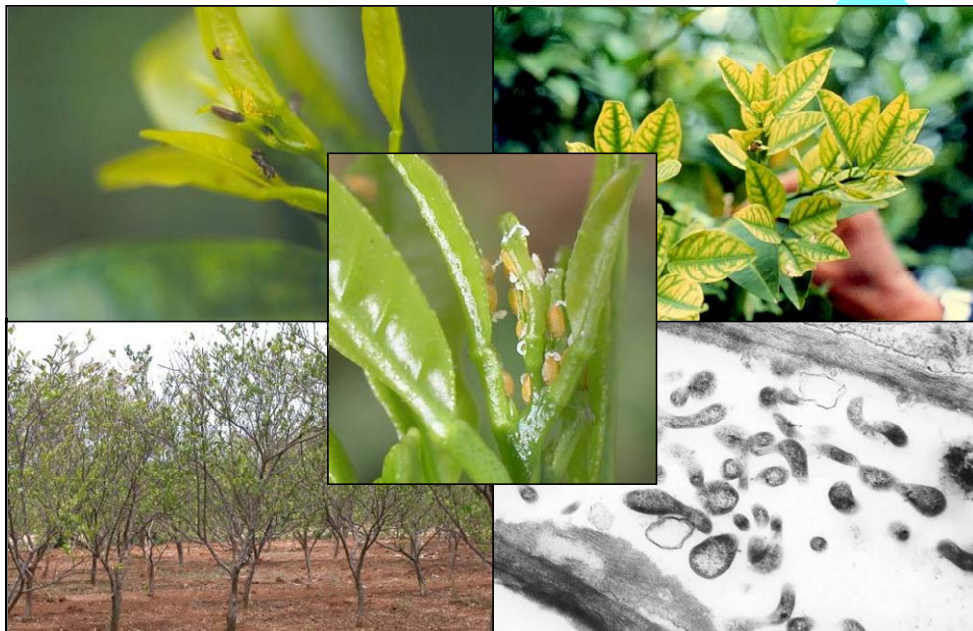
The authors thank David Mabblerley (Royal Botanic Gardens, Kew), Paul Holford and Tony Haigh (University of Western Sydney), Susan Halbert (Florida Department of Agriculture and Consumer Services) and Paul De Barro (CSIRO Entomology) for their contributions. Preparation of the document would not have been possible without funding provided by the Australian Centre for International Agricultural Research (ACIAR) and the Department of Education, Science and Training (DEST) for research on huanglongbing and the integrated control of citrus pests in China, Indonesia, Thailand, Malaysia and Viet Nam. We thank Dr Cen Yijing (South China Agricultural University), Ms Yang Yueping (Guangdong Entomological Institute) for translation of Chinese texts, and Martha Nemeth (University of California, Riverside) for obtaining some rare documents.

Version 2: 10 February 2009

Précis

Huanglongbing (HLB) and its vectors pose a major pest and disease threat to the Australian citrus and nursery industries, and to rare and endangered indigenous species of *Citrus*.

In developing this incursion management plan for HLB and its vectors, we began with the premise that generic plans would be of limited value. Comprehensive plans based on careful analysis of off-shore threats and the opportunities to respond to these threats, was seen as a better approach. But the plans required careful analysis of the scientific literature and not just recent literature reviews (which we subsequently found contain inaccuracies and oversights) or recent ‘western’ literature. Some of the most valuable and interesting literature was from China and India in the early 20th Century, some rare and not previously cited. The plan required a thorough review of the origins of *Citrus*, the HLB pathogens, and the vectors of the pathogens.



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Disclaimer

The information contained in this document is based on knowledge and understanding at the time of writing. However because of advances in science, changing legislation etc, users are reminded of the need to ensure that information on which they rely is up to date and to check the currency of the information contained herein.

¹ Calligraphy: Yang Yueping. Photographs clockwise from top right: leaf symptoms, Pat Barkley, China, 1979; bacteria in phloem sieve tubes (Lafleche & Bové 1970b), dying 4-5 year-old orchard, GAC Beattie, Indonesia, 2003; adult *D. citri* and eggs, GAC Beattie, China, 1979. Centre: *D. citri* nymphs and honeydew, GAC Beattie, Việt Nam, 2006.

Table of Contents

GLOSSARY	7
ACRONYMS.....	12
INTRODUCTION AND RECOMMENDATIONS	13
PRE-INCURSION REQUIREMENTS	15
POST-INCURSION ACTION RESPONSE PLAN.....	16
When National Eradication Is Feasible	16
When National Eradication Is Not Feasible.....	17
PEST INFORMATION.....	19
BACKGROUND INFORMATION	19
ESTIMATED IMPACT ON PRODUCTION, TRADE, ALLIED INDUSTRIES AND NATIVE ECOSYSTEMS	28
Impact on Citrus Production - General.....	28
Impact on Nursery Production.....	29
Cost of Extra Treatments - Orchards.....	30
Cost of Extra Treatments – Nurseries and Budwood Scheme.....	30
AUSTRALIAN CITRUS INDUSTRY	32
National Plantings Database	34
IMPACT OF HLB ON AUSTRALIAN CITRUS INDUSTRY	35
Postharvest Impacts	35
Impacts on Allied Industries	36
Estimating Impact on Trade and Market Access Implications	36
AUSTRALIAN CITRUS BUDWOOD SCHEME	36
AUSTRALIAN CITRUS AND ORNAMENTAL NURSERY INDUSTRIES.....	37
IMPACT OF HLB ON AUSTRALIAN CITRUS BUDWOOD SCHEME AND THE CITRUS AND ORNAMENTAL NURSERY INDUSTRIES.....	39
IMPACT ON HOME GARDENS.....	40
IMPACT ON NATIVE ECOSYSTEMS	40
RETAIL STORES AND WEEKEND MARKETS.....	41
E-commerce.....	41
PHYTOSANITARY CONDITIONS ON CITRUS IMPORTS	42
PATHWAYS AND INTERCEPTIONS.....	43
THE VECTORS AND RELATED PSYLLIDS	48
<i>Diaphorina citri</i>	48
Distribution of <i>D. citri</i>	48
Hosts of <i>D. citri</i>	49
Description of <i>D. citri</i>	49
Biology and ecology of <i>D. citri</i>	53
Damage caused by <i>D. citri</i>	54
<i>Trioza erytreae</i>	56

Distribution of <i>T. erytrae</i>	56
Hosts of <i>T. erytrae</i>	56
Description of <i>T. erytrae</i>	56
Biology of <i>T. erytrae</i>	58
Damage caused by <i>T. erytrae</i>	59
Other psyllids.....	60
Distribution and hosts of other psyllids	60
PATHOGEN ACQUISITION AND TRANSMISSION.....	60
<i>Diaphorina citri</i>	61
<i>Trioza erytrae</i>	62
HUANGLONGBING	63
Distribution of the disease	63
Huanglongbing pathogens	64
Symptomatology of HLB in <i>Citrus</i>	67
Symptomatology of HLB in <i>Murraya</i> spp.	74
Symptomatology of HLB in <i>Murraya</i> spp.	74
Mixed infections of HLB and CTV	74
Confusion with Other Diseases and Nutrient Disorders	75
Ultrastructural Changes	79
Graft Transmission and Uneven Distribution of Pathogen in Tree	80
Seed Transmission	82
Dodder Transmission	84
Potential Transmisssion by Dodder Laurel	86
HLB Epidemiology	86
Detection	91
Symptomatology	91
Spectral Characteristics.....	91
Biological indexing.....	91
Iodine Starch Test (IST).....	92
Gentisyl- β -glucose.....	93
Monoclonal Antibodies.....	93
Electron and Light Microscopy.....	93
DNA Hybridisation and PCR.....	94
Detection of 'Ca. Liberibacter' in Psyllids	97
Degree of Testing in Areas where HLB is Endemic	98
Sampling Methodologies for PCR	98
Seasonality developmental stages of the host(s) and climatic conditions	98
Tissue type	100
Collecting samples of suspect material	100
Data collection	101
Sampling protocol.....	101

Collection of samples from symptomatic field trees	102
Sample handling and shipping	102
Samples from remote sites	103
Submission form	103
Assigned laboratories	104
Criteria for the determination of a positive or negative result.....	104
Notification of symptoms.....	104
Sampling protocol for submission of suspect psyllid samples	105
STATE CONTACT OFFICERS	105
State	105
National	106
Citrus Australia Limited	106
Nursery and Garden Industry	107
THE EXOTIC PLANT PEST HOTLINE	107
SURVEILLANCE	107
Survey Precautions	108
Post- incursion Pre-endemic Specific Surveys	108
Post- incursion Pre-endemic Delimiting Surveys.....	109
Survey Methodology for Psyllids.....	112
Survey Methodology for HLB.....	114
Recommended Post- Incursion Pre-endemic Delimiting Survey Methodology for HLB.....	114
Recommendations for Australian surveys.....	116
AWARENESS.....	116
Pre-Incursion Awareness Needs	117
Post-Incursion Awareness.....	117
Current HLB Awareness Material in Australia	119
DAFF - Northern Australia Quarantine Strategy (NAQS) Fact Sheets.....	119
ERADICATION	120
Quarantine Zones	121
Scenarios	121
Detection in a backyard urban area.....	124
Detection in a backyard urban area near a commercial area.....	124
Detection in a commercial orchard.....	124
Detection in a nursery (wholesale, retail).....	125
Detection in a packing shed or juice factory	125
Monitoring e-commerce sales of citrus material.....	126
Weekend markets selling citrus trees, <i>Murraya</i> spp. or kaffir lime leaves.....	126
Trace-backs.....	126
Shipment of Hosts of Asiatic or African Citrus Psyllid.....	126
LEGISLATION	128
COST SHARING.....	129

OWNER REIMBURSEMENT.....	129
POST-INCURSION MANAGEMENT OF ENDEMIC HLB AND ITS VECTORS	130
Surveys for endemic HLB	130
Effective management of HLB	130
CONTACTS FOR FURTHER INFORMATION.....	132
Australian expertise	132
Overseas expertise	134
APPENDICES.....	137
Appendix I: Systematics of the genus <i>Citrus</i> and some <i>Citrus</i> relatives	138
The genus <i>Citrus</i>	138
The genera <i>Murraya</i> , <i>Merrillia</i> , <i>Bergera</i> and <i>Clausena</i>	140
Appendix II: Origins of <i>Citrus</i>	142
Appendix III. Origins of huanglongbing	145
Appendix IV. Spread of huanglongbing through Asia	155
Appendix V: Hosts of huanglongbing	159
Appendix VI: Hosts of <i>D. citri</i>	169
Appendix VII: Hosts of <i>T. erytrae</i>	176
Appendix VIII. Origins of <i>D. citri</i> and <i>T. erytrae</i>	178
Appendix IX: Nomenclature, systematics and general biology of the Psylloidea.....	181
Appendix X: Biology and ecology of <i>D. citri</i> and <i>T. erytrae</i>	182
<i>Diaphorina citri</i>	182
<i>Trioza erytrae</i>	191
Appendix XI: Management of huanglongbing and its vectors, <i>D. citri</i> and <i>T. erytrae</i>	197
Appendix XII. Australian Psylloidea including <i>Diaphorina tryoni</i> (Froggatt)	225
REFERENCES	230

GLOSSARY

Wherever available, definitions are those of the International Plant Protection Convention as detailed in the International Standards for Phytosanitary Measures, Publication No. 5 (2007): *Glossary of Phytosanitary Terms*.

Area:	An officially defined country, part of a country, or all or parts of several countries. [ISPM No.5]
Area of low pest prevalence:	An area , whether all of a country, part of a country, or all or parts of several countries, as identified by the competent authorities, in which a specific pest occurs at low levels and which is subject to effective surveillance, control or eradication measures [IPPC, 1997]
Buffer zone:	An area surrounding or adjacent to an area officially delimited for phytosanitary purposes in order to minimize the probability of spread of the target pest into or out of the delimited area, and subject to phytosanitary or other control measures, if appropriate [ISPM No. 10, 1999; revised ISPM No. 22, 2005; CPM, 2007]
Contact premises:	A premises containing susceptible host plants, which are known to have been in direct or indirect contact with an infested premises or infected plants. Total movement control is imposed.
Containment:	Application of phytosanitary measures in and around an infested area to prevent spread of a pest [FAO, 1995]. The use of specified survey, inspection and control strategies to restrict the distribution of a pest to a defined area.
Control (of a pest):	Suppression, containment or eradication of a pest population. [ISPM No. 9]
Control Area:	A regulated area which an NPPO has determined to be the minimum area necessary to prevent spread of a pest from a quarantine area [CEPM, 1996]. A Control Area will be imposed around the restricted area and include all remaining suspect premises. The purpose of the control area is to regulate movement of susceptible plant species for as long as is necessary to complete trace-back and epidemiological studies. Movement controls will apply and the area surveyed regularly. Once the limits of the disease have been confidently defined, the control area boundaries and movement restrictions should be relaxed or removed.
Delimiting survey:	A survey conducted to establish the boundaries of an area considered to be infested by or free from a pest. [ISPM No. 10]
Detection survey:	A survey conducted in an area to determine if pests are present. [ISPM No. 10]
Efficacy (treatment):	A defined, measurable, and reproducible effect by a prescribed treatment [ISPM No. 18, 2003]
Emergency action:	A prompt phytosanitary action undertaken in a new or unexpected phytosanitary situation [ICPM, 2001]
Emergency measure:	A phytosanitary measure established as a matter of urgency in a new or unexpected phytosanitary situation. An emergency measure may or may not be a provisional measure [ICPM, 2001; revised ICPM, 2005].
Endangered area:	An area where ecological factors favour the establishment of a pest whose presence in the area will result in economically important loss. [ISPM No. 11]

Entry (of a pest):	Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled [FAO, 1995]
Eradication:	Application of phytosanitary measures to eliminate a pest from an area [FAO, 1990; revised FAO, 1995; formerly eradicate]. It is the permanent elimination of the introduced pest or pathogen from the ecosystem which, in practice, means that it can no longer be detected by recommended methods of survey and diagnosis.
Establishment:	Perpetuation, for the foreseeable future, of a pest within an area after entry.
Exotic:	Not native to a particular country, ecosystem, or ecoarea (applied to organisms intentionally or accidentally introduced as a result of human activities).
Find free:	To inspect a consignment , field or place of production and consider it to be free from a specific pest [FAO, 1990]
Germplasm:	Plants intended for use in breeding or conservation programmes [FAO, 1990].
Growing season:	Period or periods of the year when plants actively grow in an area , place of production or production site [FAO, 1990; revised ICPM, 2003]
Host pest list:	A list of pests that infest a plant species, globally or in an area [CEPM, 1996; revised CEPM, 1999]
Host range:	Species capable, under natural conditions, of sustaining a specific pest or other organism [FAO, 1990; revised ISPM No. 3, 2005]
Incursion:	An isolated population of a pest, new to an area, recently detected and expected to survive for the immediate future.
Infested Premises:	A premise on which the exotic pest is confirmed or presumed to exist. Total movement control is imposed.
Inspection:	Official visual examination of plants , plant products or other regulated articles to determine if pests are present and/or to determine compliance with phytosanitary regulations [FAO, 1990; revised FAO, 1995;]
Introduction:	The entry of a pest resulting in its establishment [FAO, 1990; revised FAO, 1995; IPPC, 1997]
Monitoring:	An official ongoing process to verify phytosanitary situations [CEPM, 1996]
Monitoring survey:	An ongoing survey to verify the characteristics of a pest population. [ISPM No. 10]
Natural enemy:	An organism which lives at the expense of another organism in its area of origin and which may help to limit the population of that organism . This includes parasitoids , parasites , predators , phytophagous organisms and pathogens [ISPM No. 3, 1996; revised ISPM No. 3, 2005]
Naturally occurring:	A component of an ecosystem or a selection from a wild population, not altered by artificial means [ISPM No. 3, 1996]
Occurrence:	The presence in an area of a pest officially recognised to be indigenous or introduced and not officially reported to have been eradicated [FAO, 1990; revised FAO, 1995; ISPM No. 17;]
Official control:	The active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or for

	the management of regulated non-quarantine pests (see Glossary Supplement No. 1) [ICPM, 2001]
Outbreak:	A recently detected pest population, including an incursion, or a sudden significant increase of an established pest population in an area.
Parasitoid:	An insect parasitic only in its immature stages, killing its host in the process of its development, and free living as an adult [ISPM No. 3, 1996]
Pathogen:	Micro-organism causing disease [ISPM No. 3, 1996]
Pathway:	Any means that allows the entry or spread of a pest [FAO, 1990; revised FAO, 1995]
Pest:	Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products. This includes insects, mites, fungi, bacteria, nematodes, and viruses.
Pest diagnosis:	The process of detection and identification of a pest [ISPM No. 27, 2006]
Pest free area (PFA):	An area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period. [ISPM No. 11]
Pest free place of production:	Place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period [ISPM No. 10, 1999]
Pest free production site:	A defined portion of a place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period and that is managed as a separate unit in the same way as a pest free place of production [ISPM No. 10, 1999]
Pest record:	A document providing information concerning the presence or absence of a specific pest at a particular location at a certain time, within an area (usually a country) under described circumstances. [ISPM No. 9]
Pest risk (for quarantine pests):	The probability of introduction and spread of a pest and the magnitude of the associated potential economic consequences (see Glossary Supplement No. 2) [ISPM No. 2, 2007]
Pest risk analysis (PRA):	The process of evaluating biological or other scientific and economic evidence to determine whether a pest should be regulated and the strength of any phytosanitary measures to be taken against it. [ISPM No. 2, 11]
Pest risk assessment (for quarantine pests):	Evaluation of the probability of the introduction and spread of a pest and the magnitude of the associated potential economic consequences (see Glossary Supplement No. 2) [FAO, 1995; revised ISPM No. 11, 2001; ISPM No. 2, 2007]
Pest risk management (for quarantine pests):	Evaluation and selection of options to reduce the risk of introduction and spread of a pest [FAO, 1995; revised ISPM No. 11, 2001]
Pest status (in an area):	Presence or absence, at the present time, of a pest in an area , including where appropriate its distribution, as officially determined using expert judgement on the basis of current and historical pest records and other information [CEPM, 1997; revised ICPM, 1998]
PFA:	Pest Free Area [FAO, 1995; revised ICPM, 2001]

Phytosanitary action:	An official operation, such as inspection, testing, surveillance or treatment , undertaken to implement phytosanitary measures [ICPM, 2001; revised ICPM, 2005]
Phytosanitary measure:	Any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of quarantine pests or to limit the economic impact of regulated non-quarantine pests. [ISPM No. 11]
Phytosanitary procedure:	Any officially prescribed method for implementing phytosanitary regulations, including the performance of inspections, tests, surveillance or treatments in connection with regulated pests. [ISPM No. 14]
Place of production:	Any premises or collection of fields operated as a single production or farming unit. This may include production sites which are separately managed for phytosanitary purposes [FAO, 1990; revised CEPM, 1999]
Plant quarantine:	All activities designed to prevent the introduction and/or spread of quarantine pests or to ensure their official control [FAO, 1990; revised FAO, 1995].
Predator:	A natural enemy that preys and feeds on other animal organisms , more than one of which are killed during its lifetime [ISPM No. 3, 1996].
Protocol:	A detailed procedure for undertaking an activity.
Provisional measure:	A phytosanitary regulation or procedure established without full technical justification owing to current lack of adequate information. A provisional measure is subjected to periodic review and full technical justification as soon as possible [ICPM, 2001].
Quarantine:	Official confinement of regulated articles for observation and research or for further inspection, testing and/or treatment [FAO, 1990; revised FAO, 1995; CEPM, 1999].
Quarantine area:	An area within which a quarantine pest is present and is being officially controlled [FAO, 1990; revised FAO, 1995]
Quarantine pest:	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled [ISPM No. 11].
Regulated area:	An area into which, within which and/or from which plants, plant products and other regulated articles are subjected to phytosanitary regulations or procedures in order to prevent the introduction and/or spread of quarantine pests or to limit the economic impact of regulated non-quarantine pests (see Glossary Supplement No. 2) [CEPM, 1996; revised CEPM, 1999; ICPM, 2001]
Regulated pest:	A quarantine pest or a regulated non-quarantine pest [IPPC, 1997]
Release (into the environment):	Intentional liberation of an organism into the environment (see introduction and establishment) [ISPM No. 3, 1996]
Restricted Area:	A restricted area will be drawn around all infested premises and include as many suspect premises as practical. The actual distance in any one direction is determined by factors such as terrain, the distribution of orchards, irrigation and management practices, the weather (particularly rainfall, temperature and prevailing winds), the distribution of other host plants on roadsides and in home gardens. The restricted area is not determined by drawing a circle of a certain diameter around the infested premises. The boundaries must be modified as new information comes to hand. A high level of

	movement control and surveillance will apply. The restricted area also includes a buffer zone around all infested and suspect premises.
Specific survey:	A procedure by which a quarantine agency obtains information on pests of concern on specific sites in an area over a defined period of time. [Based on ISPM 6]
Spread:	Expansion of the geographical distribution of a pest within an area [FAO, 1995]
Surveillance:	An official process, which collects and records data on pest occurrence or absence by survey, monitoring or other procedures. [ISPM No. 9]
Survey:	An official procedure conducted over a defined period of time to determine the characteristics of a pest population or to determine which species occur in an area [FAO, 1990; revised CEPM, 1996].
Survey Form:	Survey forms will be completed for each premises inspected for citrus canker. Survey forms provide information to the Consultative Committee on Exotic Plant Pests, and Diseases (CCEPP). They will use the information to make decisions regarding the location of quarantine boundaries.
Systems approach(es):	The integration of different risk management measures, at least two of which act independently, and which cumulatively achieve the appropriate level of protection against regulated pests [ISPM No. 14, 2002; revised ICPM, 2005]
Specimen Report:	Specimen reports are completed whenever suspect plant samples are collected for diagnosis. The report will provide location details and other important information that will assist in managing the outbreak.
Suspect Premises:	A premise containing plants which may have been exposed to an exotic pest and which will be subjected to quarantine and intense surveillance until the pest status is clearly established. Provided there is no evidence of infection/ infestation, the premises then reverts to normal status.
Surveillance:	An official process which collects and records data on pest occurrence or absence by survey , monitoring or other procedures [CEPM, 1996]
Survey:	An official procedure conducted over a defined period of time to determine the characteristics of a pest population or to determine which species occur in any area. [ISPM No.10]
Technically justified:	Justified on the basis of conclusions reached by using an appropriate pest risk analysis or, where applicable, another comparable examination and evaluation of available scientific information [IPPC, 1997]
Verification survey:	A survey to verify the freedom from a pest of an area, prior to the establishment of a pest free area.

ACRONYMS

ACIAR	Australian Centre for International Agricultural Research
AQIS	Australian Quarantine and Inspection Service
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AusAID	Australian Agency for International Development
BA	Biosecurity Australia
CCEPP	Consultative Committee on Exotic Plant Pests and Diseases
CAL	Citrus Australia Limited
CPPO	Chief Plant Protection Officer (Commonwealth)
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry
EMAI	Elizabeth Macarthur Agricultural Institute, NSW Department of Primary Industries
ICON	Import Conditions Database
IMP	Incursion Management Plan
IPHRWG	Interstate Plant Health Regulation Working Group
IPPC	International Plant Protection Convention
ISPM	International Standards for Phytosanitary Measures
IST	Iodine starch test
NAQS	Northern Australia Quarantine Strategy
NGIQ	Nursery & Garden Industry Queensland
NMG	National Management Group
OCPPO	Office of the Chief Plant Protection Officer (Commonwealth)
PHA	Plant Health Australia
PHC	Plant Health Committee
PIMC	Primary Industries Ministerial Council (formerly ARMCANZ)
PISC	Primary Industries Standing Committee (formerly SCARM)
QDPI	Queensland Department of Primary Industries
SCARM	Standing Committee on Agriculture and Resource Management
SPS	The Agreement on Sanitary and Phytosanitary Measures
UWS	University of Western Sydney
WTO	World Trade Organization

INTRODUCTION AND RECOMMENDATIONS

This contingency plan was prepared to provide information relevant to the implementation of *PLANTPLAN: Australian Emergency Plant Pest Response*, (Plant Health Australia 2004a) in the event of incursions of huanglongbing, a serious disease of citrus, and its known vectors, the Asiatic citrus psyllid *Diaphorina citri* Kuwayama [Hemiptera: Sternorrhyncha: Psylloidea: Psyllidae] and the African citrus psyllid *Trioza erythrae* del Guercio (Hemiptera: Sternorrhyncha: Psylloidea: Triozidae). The plan must be revised regularly to incorporate rapidly changing knowledge about host plants, advances in detection techniques for the pathogen, the distribution of the pathogens and the vectors, surveillance methodology and improvements in control methods.

'*Candidatus* L. asiaticus', which causes the Asiatic form of HLB, and its vector, *D. citri*, represent significant threats to commercial citrus production in Australia and to the six species of *Citrus* that are native to Australia: *C. australis*, *C. australasica*, *C. garrawayi*, *C. glauca*, *C. gracilis* and *C. inodora*^{2,3}. All citrus producing regions of Australia have climates that are favourable for *Ca. Liberibacter asiaticus* and *D. citri*.

'*Ca. L. africanus*' and its natural vector, *T. erythrae*, also represent threats to commercial citrus production in Australia and native *Citrus* species, though, if introduced, their impact is likely to be greatest in the temperate southern regions of the mainland rather than in the subtropical and tropical northern regions and limited by the absence of their principal alternative hosts.

The vulnerability to the citrus industry Australia-wide derives from:

- Australia's proximity to the islands of the Indonesian Archipelago where both HLB and *D. citri* are endemic, and to the island of New Guinea, where their eastern-most distribution is currently in the region of Vanimo (2° 40' S, 141° 61' E) in northeastern Papua New Guinea (Davis et al. 2000, 2005, Weinert et al. 2004, OEPP/EPPO 2005a, Bové 2006);
- the continuity of indigenous citrus around the Australian coastline — *Glycosmis* spp. in thickets in northern Australia (Armstrong 1975, Sykes 1997), and *C. australasica*, *C. australis*, *C. garrawayi* and *C. inodora* in rainforests along the east coast (Armstrong 1975, Sykes 1997) and *C. glauca* from north of Emerald, through central Queensland, and New South Wales to the Flinders Ranges in South Australia (Sykes 1999);
- the widespread occurrence of orange jasmine, *Murraya paniculata*⁴, in gardens,
- wild forms of *M. paniculata* including *M. paniculata* var. *ovatifoliolata* (Brophy et al. 1994, Mabberley 1998) in coastal and sub-coastal monsoon vine-thickets on stabilised dunes or lateritic ledges above the beach; vine-thickets on rock outcrops in open woodland in Western Australia, Northern Territory and Queensland (Brophy et al. 1994);
- based on current evidence all species and varieties of *Citrus* are likely to be susceptible to HLB (Appendix V);

² Full systematic details of the taxa mentioned in the text are presented in host record tables (Appendices I-IV): exceptions occur when species are not mentioned in the tables and in some instances for continuity and to avoid confusion. Some synonyms are also given in the host record tables and these are numerous. Abbreviations for genera are used in the body of the text after the first mention of the scientific name of a species in full, but not in tables, headings and in references. For example, *Citrus medica* becomes *C. medica*, *Clausena anisata* becomes *Cl. anisata*, *Diaphorina citri* becomes *D. citri* and *Trioza erythrae* becomes *T. erythrae*. Citation of species of *Citrus* is based on Mabberley (1997, 1998, 2001, 2002, 2004), discussions with David Mabberley, and on Zhang et al. (2008) in the Flora of China: http://huh.harvard.edu/china/mss/volume11/Rutaceae-CAS_final.htm. True species, as recognised by Mabberley, are listed in Appendix I. There are about 25: more than the 16 recognised by Swingle & Reece (1967) and less than the 159 recognised by Tanaka (1977). The scientific name for curry leaf is given as *Bergera koenigii* L., not *Murraya koenigii* (L.) Spreng. Citation of species of *Clausena* is based on Molino (1994).

³ The disease also represents a serious threat to rare and endangered native *Citrus* species in New Guinea and New Caledonia. Good photographs of some Australasian species, excluding those from New Caledonia, can be viewed on Mike Saalfeld's website (<http://www.saalfelds.freemove.co.uk/HobbyCitrusGrowers.htm>).

⁴ In this document the common cultivated ornamental form of orange jasmine is considered to be *Murraya paniculata* (L.) Jack var. *exotica* (sensu Huang) (Huang CC. 1959. Preliminary study on Chinese Rutaceae. Acta Phytotaxonomica Sinica 7: 69-124. 15 plates), unless otherwise stated. The status of the species is complex and resolution of this uncertainty is the objective of a PhD being undertaken at the University of Western Sydney by Nguyen Huy Chung.

- suitability of plants as hosts of *D. citri* (Appendix VI) and *T. erytrae* (Appendix VII) varies with genotype, phenotype, and extent and frequency of leaf flushing; and
- all citrus producing regions of Australia have climates that are favourable for ‘*Ca. L. asiaticus*’ and *D. citri*: the most southern regions have climates that may also be suitable in some years for ‘*Ca. L. africanus*’ and *T. erytrae*.

The most likely pathways of entry of HLB and its vectors are:

- illegal introductions of budwood from South Africa, Brazil, Asia or Florida by growers seeking to gain advantage through new or improved varieties;
- householders illegally importing budwood or cuttings from trees owned by friends or relatives in countries where HLB occurs;
- legal importation of infested or infected material that has been inadequately tested or treated and inspected, as in recent introductions of fresh *B. koenigii* leaves to California from Hawaii, or tested⁵; what is most disturbing is that further introductions of *D. citri* came in to California from Hawaii on non-host herb shipments of malungai (*Moringa oleifera* Lam. [Brassicales: Moringaceae]) in November 2008⁶, and sweet basil leaf (*Ocimum basilicum* L. [Lamiales: Lamiaceae]) and January 2009;
- passive transport of adult psyllids, which are strongly attracted to light, in commercial and military aircraft (the latter being a possible explanation for the recent detection of *D. citri* in Guam);
- air movements (e.g., cyclonic and jet streams) carrying psyllids from areas where HLB and *D. citri* occur e.g., the Indonesian Archipelago and New Guinea;
- movement of people carrying citrus fruits and other plant material across the Torres Strait from Papua New Guinea, principally by sea; and
- unregulated landings of boats carrying citrus from other areas to the north of Australia.

The disease is not reported to be spread by contamination of people or equipment nor by movement of the pathogen in the air or in water droplets. Doubts remain concerning transmission, which was reported by Tirtawidjaja et al. (1981), but recent information indicates that HLB may be transmitted through seeds to the resulting seedlings at low levels (see, Graham et al. 2008, Hartung et al. 2008, Sagaram et al. 2008, Shatters 2008, Zhou et al. 2008a). This has led to a US Federal Import Quarantine Order (DA-2008-06) prohibiting the importing of seeds from species of known host genera (Appendix V) in the family Rutaceae from countries where HLB is present.

Plant Health Australia (PHA) and the Office of the Chief Plant Protection Officer (OCPPPO) rate HLB as of *medium-high entry potential*, with the most likely entry pathways being via illegal importation of budwood and wind assisted movement of infective vectors into northern Australia; of *high establishment potential*, based on suitable climate, a history of establishment overseas and the fact that symptoms are not easily recognised in the field; of *high spread potential*, due to suitable climate, a history of spread into new areas, vector transmission with no known natural enemies of the vector in Australia and the possibility of disease transmission by other phloem feeders; and *high economic impact*, given that the disease is extremely difficult to control and there is no evidence elsewhere of successful eradication of the disease (Plant Health Australia 2004b, Evans & Dempsey 2000). Naumann (2002) rated *D. citri* and *T. erytrae* as having high potential to establish and spread, with high priority rankings as key citrus pests. In the PHA Emergency Plant Pest Response Deed - list of categorised Emergency Plant Pests, HLB caused by ‘*Ca. Liberibacter asiaticus*’ is listed as a category 2 Emergency Plant Pest (EPP)⁷ (80% public funding: 20% private

⁵ See Wilkinson (2007) and Filippini (2008)

⁶ California Department of Food and Agriculture, Pest Exclusion Advisory 32-2008 – Asian Citrus Psyllid Found in Hawaiian Herb Shipment.

⁷ Category 2 pests are those which, if present in Australia and not eradicated would:

funding) and *D. citri* as a category 3 pest (50% public funding: 50% private funding). Other forms of '*Ca. Liberibacter*' and *T. erytrae* are not currently included in the EPP Plant Response Deed.

PRE-INCURSION REQUIREMENTS

Pre-incursion requirements include:

- a 'whole of supply chain' economic impact analysis to assess the economic costs of a possible incursion, and justification of eradication, and in the event that eradication is not feasible, of management strategies. (The benefits of the mitigation strategies should outweigh the long-term costs to the Australian citrus industry and the wider community)⁸;
- government and industry agreement on a decision key for responses to scenarios as outlined on page 123;
- '*Ca. L. americanus*' and '*Ca. L. africanus*' and *T. erytrae* included in the EPP Plant Response Deed as category 2 pests.
- a PHA schedule of owner reimbursement costs that reflects current costs, and is tailored to different varieties, production areas and tree age, accepted by the Australian citrus industry;
- prohibition of imports of fresh kaffir lime (*C. hystrix*) from any country/state with HLB and Asian citrus psyllid including the United States of America (USA),
- effective procedures for intercepting the psyllid vectors of HLB and whole plants, budwood, leaves and fruit of *Citrus* and related genera, particularly *Murraya* and *Berberis*;
- importation protocols for rootstock seeds from countries where HLB occurs should be reviewed;
- heat treatment of seed should be an essential requirement for entry of citrus seed from any country with HLB;
- ICON must be updated in light of recent changes to the systematics and nomenclature of the Rutaceae, and as new hosts of HLB are reported. Post-entry quarantine requirements for *Citrus* and *Citrus* relatives need to be revised, particularly hosts of HLB⁹;
- effective quarantine, including thorough indexing of *Citrus* and related genera in post-entry quarantine—as a precaution species of *Berberis* and *Clausena* that have not been confirmed as hosts to date should be prohibited, as detection of the HLB pathogens in these genera may be problematic, as it has been in *Murraya*;
- the draft diagnostic protocols for the detection of the Asiatic citrus psyllid (*D. citri*) and the African citrus psyllid (*T. erytrae*) (Malipatil & Semeraro 2007) must be revised and peer reviewed;
- the HLB diagnostic protocols commissioned by PHA should be completed as soon as possible;
- a process implemented and supported by legislation, that ensures those involved in the nursery industry (and especially those growing *Citrus* and *Citrus* relatives, particularly *Murraya* and *Berberis*), are identified and address details are current; this must include producers and sellers at 'flea market' retail outlets;
- effective avenues for ensuring industry and public awareness of the dangers posed by illegal introductions of plant material;

• cause significant public losses either directly through serious loss of amenity, and/or environmental values and/or effects on households, or indirectly through very severe economic impacts on regions and the national economy, through large trade losses with flow on effects through the economy; and

• impose major costs on the affected cropping sectors such that the cropping sectors would benefit significantly from eradication.

⁸ Alam & Rolfe (2006) noted that there are private and social dimensions to control and eradication programs that need to be economically evaluated to justify investment in response strategies.

⁹ All host plants of '*Ca. Liberibacter* spp.' should be treated identically with commercial *Citrus* spp. in relation to post-entry quarantine requirements for imported nursery stock, budwood or cuttings. This is not currently the case in ICON.

- surveillance for incursions, including maintenance of current NAQS and QDPI activities in northern Australia, and establishment of surveillance programs for nurseries, orchards, urban areas and areas, where native or naturalised hosts of HLB and its vectors occur;
- Department of Agriculture inspectors who regularly monitor pests, e.g., fruit fly traps on trees in orchards and residential properties, should be trained to recognise HLB vectors and symptoms;
- surveillance methodologies in place for monitoring incursions by HLB and/or its vectors;
- orchard and nursery management, including propagation of trees using high-health status budwood and rootstocks from Auscitrus, and monitoring (self-surveillance) for psyllids and HLB symptoms by growers and nurserymen;
- State and Federal permits for the use of insecticides (e.g., the organophosphates azinphos-methyl, chlorpyrifos and methidathion, the carbamate carbaryl, and the neonicotinoid imidacloprid) for control of *D. citri* and *T. erytrae* (see Appendix XI);
- permits for importation of the primary parasitoids of *D. citri* and *T. erytrae*;
- effective avenues for ensuring general awareness of symptoms of HLB and the means of recognising adult and immature stages of *D. citri* and *T. erytrae*;
- production and dissemination of resource material on HLB and its vectors should be co-ordinated between the states, OCPPO, PHA and industry and should be targeted at citrus nurserymen, growers, consultants and others and should be informative, without being too technical;
- maintenance of expertise in citrus pathology and entomology, particularly HLB symptomatology, epidemiology, diagnostics and the biology, ecology and control of *D. citri* and *T. erytrae*;
- training of inspectors, horticulturists, CITTgroup co-ordinators, and IPM scouts by (a) pathologists with field experience with HLB and knowledgeable in disease symptomatology and epidemiology and awareness of diseases/disorders with which HLB can be confused, and (b) entomologists with knowledge of the biology, ecology and management of the vectors;
- training of growers and nurserymen in vulnerable areas e.g., Ord River (Western Australia), Darwin (Northern Territory) and northern Queensland; and
- an accompanied group of 10-15 citrus growers, nurserymen, IPM scouts and Industry Development Officers should travel to Florida to see the effects of HLB, and how Florida citrus nurserymen and growers are dealing with HLB and its vector.

POST-INCURSION ACTION RESPONSE PLAN

When National Eradication Is Feasible

The following general recommendations should be adopted in the event of an incursion of HLB and/or its vectors when national eradication is deemed feasible:

- establishment of quarantine zones based on scenarios related to the climate, topography, size and degree of isolation of locations (e.g., towns, cities and orchards) where citrus and/or alternative hosts (e.g., *Murraya*) of the disease and its vectors occur, and regions where native hosts occur naturally (Appendix V);
- guidelines for delimiting surveys, including trace-back and trace-forward analyses (see page 109);
- responses based on where host plants are located in relation to the initial point of detection (see decision key on page 123);

- for situations where HLB is detected in the presence or absence of one or both vectors, mandatory¹⁰ and immediate destruction of HLB-infected plants by cutting each trunk or stem and applying glyphosate, or an alternative herbicide, to the stump to kill the roots;
- for situations where eradication of *D. citri* or *T. erytrae* in the absence of HLB (determined by surveys and PCR-testing of fifth instar and adult psyllids) may be feasible the following actions are recommended:
 - immediate application of recommended insecticides¹¹ to all host plants;
 - skeletonisation of all *Citrus* trees in orchards, home gardens and elsewhere (excluding nurseries)¹²;
 - skeletonisation of, and removal of all leaves from, grafted *Citrus* trees, and destruction of all seedling rootstocks in nurseries; and
 - elimination of all *Murraya*, *Bergera* and *Clausena* shrubs and trees;
- mandatory destruction of abandoned orchards within quarantine zones, without the need to determine the presence of HLB or its vectors; and
- regulations prohibiting transport of hosts of HLB, *D. citri* and *T. erytrae* (e.g., nursery trees, budwood, fruit and seeds) to unaffected areas.

Presence of HLB in the absence of its vectors will most probably lead to the death of infected host plants and the disease would, therefore, not be viewed as a severe threat to the industry. Nonetheless, tree eradication should occur as soon as possible after confirmation of infection.

When National Eradication Is Not Feasible

The following recommendations should be adopted to prevent occurrence and spread of HLB in post-incursion circumstances where the disease and one or both of its vectors occur in orchards in industry-recognised minor and major production areas, and where eradication of the disease and its vectors on a national basis is not considered feasible:

- mandatory area-wide management practices within orchards and surrounding areas;
- quarterly, or more frequent, monitoring by trained personnel for symptoms of HLB in known host plants (*Citrus* and *Citrus* relatives; see Appendix IV) in orchards, nurseries, home gardens and other circumstances (e.g., parks and native vegetation) where hosts of the disease and the vectors may occur within the production area;
- confirmation of HLB infection in symptomatic leaves based on use of PCR or, alternatively, if validated as appropriate, the iodine starch test (IST) in conjunction with light microscopy to detect phloem degeneration;
- mandatory¹³ and immediate destruction of HLB-infected plants by cutting each trunk or stem and applying glyphosate, or an alternative herbicide, to the stump to kill the roots (this must be done without waiting to harvest any mature fruit);
- mandatory and immediate destruction of all trees in a block should the percentage of HLB-infected trees in a block reach or exceed 10% of trees within an interval of 12 months;
- mandatory destruction of abandoned orchards;

¹⁰ Legislation will be required for mandatory removal of host plants in the absence of positive HLB determinations e.g., abandoned orchards.

¹¹ Insecticides available for suppressing psyllid populations include the organophosphates azinphos-methyl, chlorpyrifos and methidathion, the carbamate carbaryl, and the neonicotinoid imidacloprid, all of which are known from overseas reports to be effective against the psyllids. Permits for the use of these chemicals need to be in place before an incursion occurs.

¹² Such action should optimise the prospect of eradication, as the psyllid cannot survive in the absence of host canopies. Skeletonising, as an alternative to tree eradication, will minimise costs and allow orchards and nurseries to return to full production sooner. It may be feasible to use defoliant in such circumstances in orchards to achieve rapid removal of foliage on the psyllid depends. However, there are currently no registered defoliant for citrus and doses (concentrations and spray volumes) required in Australia would need to be determined. Outcomes are likely to be variable depending on chemical rate, spray application method, tree age, water relations and environmental conditions at time of application. It may be possible to apply defoliant with insecticides, but the feasibility of such tank mixes would need to be carefully considered.

¹³ Legislation will be required for mandatory removal of host plants in the absence of positive HLB determinations e.g., abandoned orchards.

- mandatory removal of HLB-infected plants in nurseries, home gardens and other circumstances (e.g., parks and native vegetation);
- mandatory removal of alternative hosts of the vectors, particularly species of *Murraya*, *Berberis* and *Clausena*, within close proximity (2 km) of orchards;
- mandatory registration of nurseries growing *Citrus* and *Citrus* relatives (particularly *Murraya* and *Berberis*);
- use of certified¹⁴ pathogen-free buds produced under a certified budwood scheme (no use of uncertified buds or marcots);
- geographical isolation of budwood sources (mother trees) and their maintenance in insect-proof screenhouses;
- geographical isolation of nurseries from orchards, and of orchards from alternative hosts of the disease and its vectors;
- nursery production, in HLB affected regions, in secure insect-proof screenhouses;
- legislation to prohibit transport of HLB-infected or vector-infested plant parts (e.g., nursery trees, budwood, fruit and seeds) to unaffected areas;
- management of planting densities, canopy dimensions and canopy densities to optimise yields per hectare¹⁵ and for effective application of sprays;
- planting of windbreaks¹⁶ to minimise movement of adult psyllids within and between orchards;
- hedging and pruning practices^{17, 18} timed and undertaken to minimise the risk of enhancing vector populations through impacts on the timing and extent of flushing;
- orchard and nursery management of *D. citri* and/or *T. erytrae* with strategically applied insecticides and mineral oils;
 - timing of sprays should be based on host-plant phenology so as to minimise feeding and oviposition and to maximise mortality of eggs, nymphs and adults;
 - application of sprays should be even and thorough, with sprays applied to run-off;
 - use of soil drenches and tree injections should be based on tree size and phenology, and account for potential loss or diminution of active ingredient(s) through leaching, degradation or tree growth;
- strategies to encourage, where feasible, biological control of the vectors by their natural enemies (e.g., planting of groundcover plants to encourage generalist predators);
- growing plants (as intercrops and/or ground-covers within orchards) that produce volatiles that repel the vectors, thereby slowing ingress of HLB into orchards;
- timing irrigation (where feasible) and fertiliser applications to regulate the timing, number and extent of flush cycles; use of supplementary overhead irrigation to reduce psyllid populations; and
- education of farm and nursery personnel; pesticide manufacturers, distributors and retailers; consultants, technical advisors, and scouts; research, quarantine, regulatory and advisory staff within government departments.

¹⁴ A mandatory certification, or an accreditation, scheme for pathogen-free or pathogen-tested citrus budwood should be implemented as a matter of high priority in Australia.

¹⁵ See: Hutton RJ, Broadbent P, Bevington KB. (2000). Viroid dwarfing for high density citrus plantings. Horticultural Reviews 24: 277-317; Albrigo LG, Syvertsen JP, Spann TM. 2007. Canopy flush control for management of canker and greening. Citrus Industry (March) pp. 12-14

¹⁶ See Owen-Turner & Hardy S. 2006. Windbreaks for Citrus. CITGroups Australia.

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/137858/Windbreaks-for-citrus.pdf

¹⁷ Bacon PE. 1981. The effect of hedging time on regrowth and flowering of mature Valencia orange trees. Australian Journal of Agricultural Research 32(1): 61–68.

¹⁸ Bevington KB. 1980. Response of Valencia orange trees in Australia to hedging and topping. Proceedings of the Florida State Horticultural Society 93: 65-66.

PEST INFORMATION

PATHOGENS

COMMON NAMES	huanglongbing (official common name, meaning 'yellow shoot disease'), citrus greening (informal common name), likubin or decline (Taiwan), leaf mottling (Philippines), citrus dieback (India), citrus vein-phloem degeneration (Indonesia), citrus greening, yellow branch or blotchy-mottle (South Africa)
SCIENTIFIC NAMES	' <i>Candidatus Liberibacter asiaticus</i> ' (Asiatic form), ' <i>Ca. L. africanus</i> ' (African form) and ' <i>Ca. L. americanus</i> ' (South American form)
SYNONYMS	' <i>Ca. Liberobacter asiaticus</i> ' and ' <i>Ca. Liberobacter asiaticum</i> ' ' <i>Ca. Liberobacter africanus</i> ' and ' <i>Ca. Liberobacter africanum</i> '

ASIATIC VECTOR

COMMON NAMES	Asiatic citrus psyllid, Asian citrus psyllid, oriental citrus psyllid, citrus psylla
SCIENTIFIC NAME	<i>Diaphorina citri</i> Kuwayama [Hemiptera: Sternorrhyncha: Psylloidea: Psyllidae]
SYNONYMS	<i>Euphalerus citri</i> Crawford

AFRICAN VECTOR

COMMON NAME	African citrus psyllid, citrus psylla
SCIENTIFIC NAME	<i>Trioza erytrae</i> (del Guercio) [Hemiptera: Sternorrhyncha: Psylloidea: Triozidae]
SYNONYMS	<i>Aleurodes erytrae</i> del Guercio; <i>Trioza citri</i> Laing; <i>Trioza merwei</i> Petty; <i>Spanioza merwei</i> (Petty); <i>Spanioza erythrae</i> (del Guercio); <i>Spanioza erytrae</i> del Guercio

'It is important to note that the category *Candidatus* is not covered by the Rules of the Bacteriological Code. Consequently, a name included in the category *Candidatus* cannot be validly published, and it also cannot be designated sp. nov., gen. nov., etc.': Euzéby JP. 2008. List of Prokaryotic names with standing in nomenclature. <http://www.bacterio.cict.fr/candidatus.html>.

BACKGROUND INFORMATION

Important background information on HLB and its vectors can be found in the following papers and reviews:

- Aubert B. 1987c. *Trioza erytrae* Del Guercio and *Diaphorina citri* Kuwayama (Homoptera: Psylloidea) the two vectors of citrus greening disease: biological aspects and possible control strategies. *Fruits* 42: 149-162.
- Aubert B. 1988b. Towards an integrated management of citrus greening disease. In: Timmer LW, Garnsey SM, Navarro L (eds), *Proceedings of the Tenth Conference of the International Organization of Citrus Virologists*, Valencia, Spain, 17-21 November 1986. Riverside: International Organization of Citrus Virologists, University of California: Riverside. pp. 226-230.
- Aubert B. 1990b. Integrated activities for the control of huanglongbing-greening and its vector *Diaphorina citri* Kuwayama in Asia. In: Aubert B, Tontyaporn S, Buangsuwon D (eds), *Proceedings of the Fourth International Asia Pacific Conference on Citrus Rehabilitation*, Chiang Mai, Thailand, 4-10 February 1990. Rome: FAO UNDP. pp. 133-144.

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- Aubert B, Quilici S. 1984. Biological control of the African and Asian citrus psyllids (Homoptera: Psylloidea), through eulophid and encyrtid parasitoids (Hymenoptera: Chalcidoidea) in Réunion Island. In: Garnsey SM, Timmer LW, Dodds JA (eds), *Proceedings of the Ninth Conference of the International Organization of Citrus Virologists*, Puerto Iguazu, Misiones, Argentina, 9-13 May 1983. Riverside: International Organization of Citrus Virologists, University of California, Riverside. pp. 100-108.
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- Bové JM. 2006. Huanglongbing: a destructive, newly-emerging, century-old disease of citrus. *Journal of Plant Pathology* 88: 7-37.
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- Halbert SE, Manjunath KL. 2004. Asian citrus psyllids (Sternorrhyncha: Psyllidae) and greening disease of citrus: a literature review and assessment of risk in Florida. *Florida Entomologist* 87: 330-353.
- Hoffmann WE. 1936. *Diaphorina citri* Kuw. (Homoptera: Chermidae), a citrus pest in Kwangtung. *Lingnan Science Journal* 15: 127-132.
- Husain MA, Nath D. 1927. The citrus psylla (*Diaphorina citri*, Kuw.) [Psyllidae: Homoptera]. *Memoirs of the Department of Agriculture India, Entomology Series* 10 (2): 5-27. 1 plate.
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- Martinez AL, Wallace JM. 1967. Citrus leaf mottle yellows disease in the Philippines and transmission of the causal virus by a psyllid, *Diaphorina citri*. *Plant Disease Reporter* 51: 692-695.
- McClellan APD, Schwarz RE. 1970. Greening or blotchy-mottle disease of citrus. *Phytophylactica* 2: 177-194.
- OEPP/EPPO. 2005. EPPO Standards. Diagnostics PM 7/52 *Diaphorina citri*. *OEPP/EPPO Bulletin* 35: 331-333.
- OEPP/EPPO. 2005. EPPO Standards. Diagnostics PM 7/57 *Trioza erytreae*. *EPPO/EPPO, Bulletin* OEPP/EPPO Bulletin 35: 271-273.
- Otake A. 1990. Bibliography of citrus greening disease and its vectors attached with indices, and a critical review on the ecology of the vectors and their control. *Japan International Cooperation Agency*. i-iv, 1-161.

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- Tirtawidjaja S, Hadewidjaja T, Lasheen AM. 1965. Citrus vein phloem degeneration virus, a possible cause of citrus chlorosis in Java. Proceedings of the American Society of Horticultural Science 86: 235-243.
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Information in all of these publications has been reviewed and updated in this document to address numerous errors in records and interpretations. A full list of papers used in preparation of this Pest Specific Contingency Plan (Incursion Management Plan) can be found in the reference list.

Websites with background information on the disease and vectors are:

<http://www.ivia.es/iocv/enfermedades/hlb/HUANGLONGBING.htm>
<http://www.californiacitrusthreat.com/huanglongbing-citrus-greening.html>
http://www.aphis.usda.gov/plant_health/plant_pest_info/citrus_greening/downloads/pdf_files/hlb-pubversion.pdf
http://www.aphis.usda.gov/plant_health/plant_pest_info/citrus_greening/index.shtml
<http://www.doacs.state.fl.us/pi/enpp/ento/citrusgreening.html>
http://www.flcitrusmutual.com/content/docs/issues/canker/SG_presentation.pdf
<http://ipm.ifas.ufl.edu/agricultural/fruit/citrus/ASP-hoy.htm>
http://www.eppo.org/QUARANTINE/bacteria/Liberobacter_africanum/LIBESP_ds.pdf
<http://www.apsnet.org/media/hottopics.asp>
http://www.aphis.usda.gov/lpa/news/2005/09/greening_ppq.html
http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=153926
<http://ccpp.ucr.edu/news/CitrusCanker&HuanglongbingDiseaseJan07.pdf>
<http://creatures.ifas.ufl.edu/citrus/acpsyllid.htm>
http://www.eppo.org/QUARANTINE/insects/Diaphorina_citri/DIAACI_ds.pdf
http://www.eppo.org/QUARANTINE/insects/Trioza_erytrae/TRIZER_ds.pdf
<http://ccpp.ucr.edu/news/PsyllidbrochureAug05.pdf>
http://www.aphis.usda.gov/ppq/ep/citrus_greening/images.html
http://www.doacs.state.fl.us/pi/caps/images/pdf_caps-az_hlb-acp_2006.pdf
<http://www.ars.usda.gov/SP2UserFiles/Place/00000000/opmp/CitrusGreening61017.DOC>
http://www.eppo.org/QUARANTINE/bacteria/Liberobacter_africanum/LIBESP_images.htm
<http://www.ivia.es/iocv/enfermedades/hlb/HUANGLONGBING.htm>

HLB is the most destructive disease of citrus. It is caused by endogenous, phloem-limited α -Proteobacteria in the genus ‘*Candidatus Liberibacter*’ that are transmitted by the citrus psyllids *D. citri* and *T. erytrae*. Three liberibacter ‘species’ have been described from citrus namely, ‘*Ca. L. asiaticus*’, ‘*Ca. L. africanus*’, and ‘*Ca. L. americanus*’ (Teixeira et al. 2005c), but they may be forms or strains of one species, ‘*Ca. L. africanus*’. *D. citri* and *T. erytrae* are able to transmit both ‘*Ca. L. asiaticus*’ and ‘*Ca. L. africanus*’; *D. citri* has recently been found to transmit ‘*Ca. L. americanus*’ (Yamamoto et al. 2006), but it is not known whether *T. erytrae* can transmit it.

Until recently, liberibacters were considered to be restricted in nature to the family Rutaceae, mostly to the sub-family Aurantioideae, although dodder (*Cuscuta australis* R. Br., *Cu. campestris* Yuncker and *Cu. ceanothi* Behr syn. *Cu. subinclusa* Dur. & Hilg. [Solanales: Convolvulaceae]) (Ghosh et al. 1977, Tirtawidjaja 1981, Garnier & Bové 1983), tobacco (*Nicotiana tabacum* L. [Solanales: Solanaceae]) (Garnier & Bové 1993, Francischini et al. 2007), tomato (*Solanum lycopersicum* L. [Solanaceae]) (Duan et al. 2008), and periwinkle *Catharanthus roseus* (L.) G. Don

(Gentianales: Apocynaceae) (e.g., Ghosh et al. 1977, Garnier & Bové 1983, Zhou et al. 2008) have been infected experimentally. However, there are recent reports of a liberibacter¹⁹ occurring naturally in tomato and potato (*Solanum tuberosum* L.), and of transmission by the potato/tomato psyllid, *Bactericera* (= *Paratrioza*) *cockerelli* (Šulc) [Psyllidae], in California (Hansen et al. 2008) and New Zealand²⁰ (Liefting et al. 2008abcd, Liefting in press ab) and in tamarillo (*Solanum betaceum* Cav.) and Cape gooseberry (*Physalis peruviana* L.) [Solanaceae] in New Zealand (Liefting et al. 2008b). The ramifications of these recent reports to *Citrus* are not clear.

Li et al. (2008) found that '*Ca. L. solanacearum*' has not been yet detected in thousands of '*Ca. L. asiaticus*'-suspect ACP adults and nymphs, nor in hundreds of HLB-suspect citrus plants samples collected in Florida, Texas, Louisiana, Hawaii and California, or from other countries (a total of 6000 samples). Conversely, none of three known liberibacter forms affecting citrus has been detected in zebra chip suspect samples of potato plants and *B. cockerelli* collected in the fields in various states in the USA. '*Ca. L. solanacearum*' from Texas has 99% homology to the New Zealand liberibacter and 96% to *Ca. L. asiaticus*.

Bextine et al. (2008) determined that the potato psyllid can survive on citrus, thus demonstrating it could potentially transmit liberibacters between cropping systems. *D. citri* on tomato died within 48 h. For the potato psyllid on citrus there was 50% survival after 5 d and <10% survival after 10 d with feeding and excrement but no reproduction ie potato psyllids did respond to citrus as a potential transitory host plant which suggests that it could be efficient at moving '*Ca. Liberibacter* sp.' from tomato/potato crops to citrus.

In addition to transmission by *D. citri* and *T. erytrae*, the pathogens can also be spread during propagation of host plants through infected grafting material and by marcotting (air-layering). The disease is not reported to be spread by contamination of people or equipment, nor by movement of the pathogen in the air or in water droplets. Doubts remain concerning seed transmission, which was reported by Tirtawidjaja et al. (1981).

HLB is the major limiting factor for citrus production in parts of Asia and Africa (Aubert 1988b, 1990c, Otake 1990, da Graça 1991, da Graça & Korsten 2004, Bové 2006a, Gottwald et al. 2007) and its impact in the Americas is increasing as the pathogen, and *D. citri*, spread through the region. In areas where the disease is endemic, trees within entire orchards may live for less than 3 years.

Although huanglongbing is the official name of the disease (Moreno et al. 1996, van Vuuren 1996, Bové 2006), it is also known by several other common names. These include the widely used citrus greening, likubin (decline) in Taiwan, citrus dieback in India, citrus leaf mottle yellows in the Philippines, citrus vein-phloem degeneration (CVPD) in Indonesia, greening or blotchy-mottle disease in South Africa, and greening disease in Florida and Brazil. The three Chinese characters for huanglongbing literally mean 'yellow dragon disease' (黄龙病). This has led to much confusion, as the intended meaning is 'yellow shoot disease', literally 'huangshaobing' (黄梢病). This confusion arose through the use of 'long' (dragon) by farmers in the Chaoshan (including Chaozhou and Shantou) region of Guangdong when referring to flush growth (young shoots) on citrus trees. Other names recorded in China and translated to English include 'yellow cock (cockerel, chicken) head' (黄鸡头), 'withering yellow', 'yellow surface disease', 'yellow crab disease', 'golden broad leaf', 'pepper leaf', and 'decline': see Lin & Lin (1990), based on Lin (1956) as translated by Lin Kung Hsun and Bernard Aubert (1990).

¹⁹ The name of this liberibacter is in dispute: Liefting et al. (2008c, in press ab) named it '*Ca. L. solanacearum*' and Hansen et al. (2008) named it '*Ca. L. psyllaurosus*'.

²⁰ See: <http://www.pestalert.org/viewNewsAlert.cfm?naid=61>, <http://www.biosecurity.govt.nz/pests/surv-mgmt/resp/tom-cap-bacterium/qa>

D. citri was recorded in Australia, in the Northern Territory in 1915, but it was eradicated by chance during the 1916-1922 eradication campaign for citrus canker (*Xanthomonas citri* subsp. *citri* (ex Hasse 1915) [Pseudomonadales: Pseudomonadaceae]) (Bellis et al. 2005).

‘*Ca. L. africanus*’ and its natural vector, *T. erythrae*, also represent significant threats to commercial citrus production in Australia and native *Citrus* species, though, if introduced, their impact is likely to be greatest in the temperate southern regions of the mainland rather than in the subtropical and tropical northern regions. Both occur in sub-Saharan Africa (OEPP/EPPO 2005b, Bové 2006a). *T. erythrae* cannot establish in hot and dry areas where midday temperatures and RH regularly reach 32°C or more combined with 30% RH (Catling 1969b, Aubert 1987c).

Surveillance relies on accurate identification of symptoms in the field by trained staff and then molecular testing of samples. Biological indexing, electron microscopy, or serology, as well as PCR techniques are needed to provide a more robust general initial detection of HLB (Okuda et al. 2005). A purely molecular approach to diagnosis is not wise (especially if negatives are obtained), since primers for ‘*Ca. L. africanus*’ and ‘*Ca. L. asiaticus*’ did not detect ‘*Ca. L. americanus*’ (Teixeira et al. 2005a, c). Other variants may exist that would not be detected by current probes.

Symptoms of HLB can be easily mistaken for symptoms stemming from other plant diseases (e.g., stem pitting strains of citrus tristeza virus and *Phytophthora* root rot), insect damage, nutrient deficiencies, and water-logging. In Australia, the disease most closely resembling HLB in terms of symptom expression is Australian citrus dieback (a phytoplasma-associated disease) (Davis et al. 1997, Broadbent 2000). In Brazil and China, phytoplasmas have been found associated with HLB-like symptoms (Chen et al. 2008, Teixeira et al. 2008d). In 2007, a phytoplasma of group 16SrIX, closely related to the pigeon pea witches’ broom phytoplasma (99% 16SrDNA sequence identity) was found associated with HLB-like symptoms in São Paulo State (SPS). The phytoplasma associated with HLB-like symptoms is probably transmitted to citrus by an insect vector²¹ becoming infected on an external non-citrus source. *Crotalaria juncea* L. [Fabales: Leguminosae] plants, grown in between citrus rows for soil improvement, have been found to be infected with the phytoplasma. Transmission of the phytoplasma from citrus to citrus has not yet been observed (Bové et al. 2008). In Guangdong, China in 2006 and 2007, 110 out of 141 citrus samples showing typical symptoms of HLB from 11 different cities, were PCR-positive for a strain of ‘*Candidatus Phytoplasma asteri*’. Many of the samples were mix-infected with ‘*Ca. L. asiaticus*’ (Chen et al. 2008).

Surveys may also be hampered by the time-lag between infection and symptom expression, which can be 1-2 years (Xu et al. 1988c, Wang et al. 1996, Gottwald et al. 2007).

During the latent phase before symptom development, detection of HLB in citrus by PCR is generally considered to be ineffective (Bové 2006a). However, Wang et al. (1996) found that of 89% of psyllid infected plants that tested positive by PCR, only 70% showed symptoms. Irey et al. (2006a,b) reported detection from asymptomatic samples with initial results indicating that actual incidence of infection based on PCR testing may be up twice the estimated incidence of infection based on the presence of visual symptoms alone.

²¹ It is very unlikely that *D. citri* would be vectors of phytoplasmas. The superfamily containing the largest number of vector species is the Membracoidea, within which all known vectors to date are confined to Cicadellidae. The second largest group is the Fulgoromorpha, in which four families of vector species are found. The smallest suborder is Sternorrhyncha, in which only two genera in the Psyllidae, *Cacopsylla* and *Bactericera*, are confirmed vectors (Weintraub & Beanland 2006).

Table 1 summarises observations of field tolerance of *Citrus* species and varieties to ‘*Ca. L. asiaticus*’, ‘*Ca. L. africanus*’ and ‘*Ca. L. americanus*’. Readers are referred to Appendix I for synonyms of species and varietal names²². Field symptomatology depends on:

- whether a tree flushed during a period of psyllid activity (de Lange et al. 1985, Koizumi et al. 1994);
- the presence and severity of CTV strains also present; and
- the form of ‘*Ca. Liberibacter*’.

Because a variety is tolerant does not reduce its significance as a reservoir of infection e.g., lemons are important reservoirs of infection, because of their more frequent flushes, which are attractive to the vector. As stated by Aubert (1990b), among the commercial varieties of citrus, HLB causes a wide range of reactions from relatively mild to extremely severe: ‘The group of acid citrus (limes and lemons) is much less sensitive than the group of sweet citrus (mandarins, oranges, tangors, tangelos) and *Poncirus*²³ is tolerant but not immune.’

Table 1. Field tolerance of *Citrus* and *Citrus* relatives to HLB.

Pathogen Country	Reference	Highly Intolerant (highly sensitive)	Intolerant	Fairly Tolerant (tolerant)	Tolerant (moderate)	Susceptible (severe)
‘<i>Ca. L. asiaticus</i>’						
Thailand	Koizumi et al. 1997				rough lemon, calamondin, Som-pan and Ladu mandarins, Sour lime (but a major source of inoculum as a backyard tree), Tahiti lime	Large numbers of sweet orange (e.g., Neck orange, Washington navel); Murcott tangor, mandarin (Fremont, Ponkan, Queen, Som-keowan, Shogun) and tangelo
Thailand	Koizumi et al. 1993, 1994			Queen mandarin, Avon Ever Bearing calamondin, rough lemon	Ladu and Som-pan mandarins ²⁴	Ortanique, Wilking, Ellendale, Pet-yala, Beauty, Onesco, Tankan, Nian-ju, sweet orange were most susceptible, followed by the mandarins Fairchild, Murcott, Kinnow, Clementine, Fremont, Ponkan, King, Som-keo-wan, Satsuma, Som-keaw and Ba-yue-ju.
Thailand	Miyakawa & Zhao 1990 Schwarz et al. 1973a,b				som-o pomelo	Som-keowan mandarin, Som-kleang sweet orange, Manao lime (symptoms masked by CTV)
Malaysia	Aubert 1992	limau kupas langkat (mandarin)				
India	Fraser & Singh 1969	All sweet oranges, blood oranges and Mosambi deteriorate quicker than Jaffa, Valencia, Hamlin and	Nagpur and Coorg mandarins, Clementine, Ladu and Emperor when infected as nursery trees, but less affected than sweet orange when infected as	trifoliate orange and its hybrids show prominent symptoms but less tree deterioration. Satsuma mandarin, kaffir lime, Ichang papeda, citron, Meyer lemon	pomelo, Cleopatra mandarin, Some native mandarins, Guntur sour orange, acid lime in northern and central India, but not in southern India, rough lemon, C.	

²² See also, though dated, Citrus of the World. A Citrus directory. Version 2.0 - September 2002. (c) SRA INRA-CIRAD 2002. ISBN 2-7380-0720-1 (Version 1.0). www.corse.inra.fr/sra/synonym.pdf.

²³ See Appendix I: *Poncirus trifoliata* (L.) Raf. is, as originally described, *Citrus trifoliata* L.

²⁴ Koizumi et al. (1994) claim that *D. citri* undergoes ‘rapid extinction’ on Ladu and Som-pan mandarins

Pathogen Country	Reference	Highly Intolerant (highly sensitive)	Intolerant	Fairly Tolerant (tolerant)	Tolerant (moderate)	Susceptible (severe)
		Sathgudi; all tangelos especially Yalaha and Orlando, mandarin hybrids (e.g., Kinnow) and some native mandarins	mature trees. Differences in susceptibility between local strains of mandarins. Grapefruit and sour orange when infected as nursery tree, but tree deterioration of adult trees takes longer than sweet orange.		<i>karma</i> , sweet lime, kaffir lime, a native lemon, Tahiti lime, adajamir, Rangpur lime, sweet lime and some rough lemons, as rootstocks, may improve performance of some susceptible scion varieties	
India	Fraser & Singh 1966			some varieties of mandarin; some rough lemons	sweet lime; Rangpur lime	All varieties of sweet orange, grapefruit (onset may be later than sweet orange); some varieties of mandarin; some rough lemons
India	Nariani et al. 1973				sweet lime, pomelo (chakotra), kaffir lime (wild in Assam, no symptoms, pathogen not isolated on indexing). Adajamir in glasshouse trials	
India	Nariani 1981			sweet lime (resistant), Italian, Eureka and Lisbon lemons (tolerant)	trifoliate orange and citranges	7 cultivars of sweet oranges, 2 mandarins (Dancy and Santra) highly susceptible
Philippines	Altamirano et al. 1976				Szinkom x Ladu hybrid mandarin, calamondin, lime, lemon	
Philippines	Salibe & Cortez 1966, Miyakawa & Zhao 1990				Ladu mandarin, sweet and sour orange, citron	Szuwuikom, Ponkan, Tankan, Batanges, calamandarin, Szibat and Szinkom mandarins, Mazoe rough lemon
Philippines	Martinez & Wallace 1969			grapefruit, sour orange, Sunki mandarin, rough lemon, Rangpur lime, Borneo red lime, Eureka lemon, Key lime, Palestine sweet lime, Shekwasha, native and Siamese pommeloos, citron showed mild-moderate leaf symptoms and slight stunting. Calamondin, alemow, and Chinese box orange showed slight leaf symptoms and stunting.	trifoliate orange, Troyer and Carrizo citranges, Chevalier's aeglopsis, and a misnamed plant (' <i>Atalantia trifolia</i> '), showed no leaf symptoms. Tolerant rootstocks conferred no resistance to the scion.	Szinkom, Sziwuikom, Sun wuikom, Batangas, Ladu, calamandarin, Ransas, Cleopatra, Ponkan, Oneco, King, Avana, Malvasio, Murcott mandarins, Madam Vinous, Pera, Hamlin, Koethen, Shamouti, Caipira, Campbell Valencia, Washington navel oranges; Orlando tangelo, Szinkom x Batangas, Szinkom x Ladu, Szinkom x King, Shekwasha x calamondin
Philippines	Gonzales & Viñas 1981			Bearss lime	sweet orange less susceptible than mandarins	Mandarins and mandarin hybrids highly susceptible
Philippines	Gonzales et al. 1972				trifoliate orange and its hybrids, lemon and sweet lime	In decreasing order of susceptibility: sweet orange, pomelo, grapefruit, hybrids of mandarin and sweet orange, mandarin
China (Taiwan)	Miyakawa 1980				Eureka lemon, sour orange grapefruit,	sweet orange, mandarins e.g., Ponkan

Pathogen Country	Reference	Highly Intolerant (highly sensitive)	Intolerant	Fairly Tolerant (tolerant)	Tolerant (moderate)	Susceptible (severe)
	(greenhouse tests, graft inoculations)				Sexton tangelo, trifoliolate orange, jasmine orange	and Orlando tangelo; kumquats
China (Taiwan)	Su & Huang 1990				Wentan and Peiyu pomelos tolerant pre-1970 but not post 1970	most cultivars
China (Taiwan)	Su & Matsumoto 1972 (glasshouse inoculations)					Valencia orange, Rangpur lime, Etrog citron, Szinkom mandarin, calamandarin, Ponkan/Sunki, Tankan/Sunki, Sunki
China	Lin 1956					Nearly all species and varieties of citrus in affected area are susceptible. Order of degree of susceptibility is: Ponkan, Chiaokan, Chachihkan, Lukan, and Tungkan mandarins, various varieties of sweet orange, Hungninmeng (a lemon x mandarin hybrid), Nienchu mandarin, Shangmayu pomelo and Shihchicha.
China	Zhao 1981, Miyakawa & Zhao 1990				trifoliolate orange (Zhao 1981)	All stock/scion combinations including Mauritius papeda (kaffir lime), Ichang papeda, honglinmon (a lemon), Shantianyou pomelo, Xuegan orange, Shinsan sour orange and Suanju. Citrange seedlings (Zhao 1981)
China	Zhao 1987				Satsuma	
China	Deng et al. 2008					HLB in pomelo potentially as severe as in sweet orange and mandarin
Indonesia	Tirtawidjaja et al. 1965 (glasshouse inoculations)					West Indian lime, grapefruit, Djeruk Siem mandarin, Palestine sweet lime, sweet orange, rough lemon, Japanese citron, and Djeruk Grant mandarin
Indonesia	Aubert et al. 1985				Pomelos more tolerant than orange or mandarin	symptoms of lopsided fruit and seed abortion on rough lemon and Rangpur lime
Brazil	Lopes et al. 2006)					sweet orange (Valencia, Pera, Natal, Hamlin, Westin, Lima verde, Bahia, Bahianinha, Folha murcha, Shamouti), mandarins (Ponkan and Cravo), Persian and Tahiti limes, Murcott tangor; jasmine orange

'Ca. L.

Pathogen Country	Reference	Highly Intolerant (highly sensitive)	Intolerant	Fairly Tolerant (tolerant)	Tolerant (moderate)	Susceptible (severe)
africanus'						
South Africa	McClellan & Schwarz 1970			well defined symptoms not seen in trifoliolate orange or Troyer citrange	grapefruit, lemons, rough lemon	The more susceptible varieties of tangerine and mandarin e.g., Satsuma are more sensitive than sweet orange. Tangelos react similarly to mandarins e.g., Orlando and Minneola are very sensitive. Most varieties of sweet orange including Valencia and Washington navel. (Hamlin and Tomango oranges appear more tolerant).
South Africa	de Lange et al. 1985			true lemon, rough lemon, and trifoliolate orange and its hybrids; lime group highly tolerant.	Gold Seal sweet orange	sweet oranges, mandarin and grapefruit, citron and shaddock
South Africa	Schwarz 1968a			Palestine sweet lime, West Indian lime, rough lemon, trifoliolate orange and its hybrids	lemon	Severe symptoms on sweet orange, many mandarin, tangelo and grapefruit varieties
South Africa	Manicom & van Vuuren 1990			lime, pomelo, trifoliolate orange and citranges	grapefruit, lemon, sour orange,	All cultivars of sweet orange (especially blood oranges), tangelo (especially Orlando and Minneola). Mandarins vary in susceptibility and symptoms severe if infected as young trees, but less severe tree deterioration than sweet orange if infected later.
South Africa	Oberholzer 1965, von Standen & Basson 1965					All major commercial varieties equally susceptible but Valencia orange shows more pronounced foliar symptoms than Washington navel
Reunion	Aubert (cited as pers. comm. in de Lange et al. 1985)				sweet orange cultivar 'Gold Seal'	

ESTIMATED IMPACT ON PRODUCTION, TRADE, ALLIED INDUSTRIES AND NATIVE ECOSYSTEMS

Impact on Citrus Production - General

HLB is a highly destructive disease of citrus. Trees infected at an early age may fail to come into production while more mature trees become unproductive soon after infection. It is the primary cause of losses in citrus production in Asia (Aubert 1990a) and there is no successful treatment of infected trees. Fruit produced by infected trees has an unpalatable flavour (Husain & Nath 1927, McClean & Schwarz 1970) and potentially may taint extracted juice products with consequent economic loss.

The damage potential was noted by Roistacher (1996), who warned that the introduction of HLB and its vector into a climatically suitable area could well result in the destruction of the citrus industry of that region, while in areas where the disease was endemic, citrus trees could live for 5-8 years and never produce usable fruit.

In areas where HLB is established and the vector is present, the damage to citrus production can be extremely high. Fraser et al. (1966) reported that the catastrophic effect of HLB in India after 1946 coincided with the expansion of irrigated citrus production in the Punjab and movement of citrus within and from this region to other regions of the subcontinent. Such catastrophic effects were initially attributed to *D. citri* by Husain & Nath (1927). They reported that: 'Of the insects pests of citrus in India, *Diaphorina citri*, Kuw., commonly known as the 'Citrus Psylla', is of the greatest importance. It is present all over the country and has been so abundant in many localities as to call for special attention. In certain tracts in the Punjab it has been responsible for very serious losses. It is not an uncommon sight to see once valuable orchards reduced to unproductive plantations of dried skeletons of trees, primarily through the ravages of this insect'.

Zhao (1981) noted that in affected areas in China an isolated orchard may be seriously affected by HLB 8-9 years after planting, and new orchards close to sources of infection could be seriously damaged before reaching production. Decline and loss of productivity of citrus trees in the Philippines due to HLB began in 1957 (Martinez & Wallace 1967). In Batanges Province in the Philippines, citrus production rose between 1955 to 1960 to a peak of 11,680 t, then declined to 6,300 t in 1964 and to 1,000 t in 1968 due to HLB, with 60-90% of trees infected in many orchards causing their abandonment (Martinez & Wallace 1968, Martinez et al. 1971) and more than 1 million trees destroyed (Martinez & Wallace 1967). HLB destroys 10-15% of tangerine trees in Thailand annually (Bové 2006a). In Réunion, an 8 year survey in the 1980s and 90s determined that 65% of trees were infected and unproductive within 7 years of planting (Gottwald et al. 1989, Gottwald et al. 2007).

Citrus rehabilitation was attempted in North Bali where the incidence of HLB was high, by total citrus eradication in all orchards and backyards, then planting of up to 1 million mandarin trees propagated from HLB-free buds. But replanting commenced before eradication was complete and within 10 years almost 100% of trees were affected (Bové et al. 2000).

As well as direct damage, HLB infection may predispose trees to other disease conditions. In mandarin orchards in Shantou in China, infection with HLB was found to result in increased damage by trunk borer and *Phytophthora* collar rot, and combined damage from the three agents was common in advanced epidemics (Aubert 1990a).

Since the 1960s, when approximately 38% of citrus trees in South Africa were infected with HLB,

and production was virtually eliminated in three major citrus areas, the incidence has dropped to 1% in 2006 (Buitendag & von Broembsen 1993, le Roux et al. 2006a). HLB is controlled by certified greening-free nursery trees, systemic insecticides to control the psyllid vector, *T. erytrae*, and removal of diseased trees to reduce inoculum levels (Buitendag & von Broembsen 1993, le Roux et al. 2006b). There is no mandatory eradication of diseased trees, although the industry would like it.

The presence of HLB in Brazil has led to the elimination of an estimated 3 million diseased trees since '*Ca. L. americanus*' and '*Ca. L. asiaticus*' were detected, in São Paulo State, in 2004 (Lopes et al. 2008). In São Paulo, where the disease is currently most widespread, 18.6% of 96,200 citrus blocks surveyed in April 2008 contained at least one infected tree. Many growers have not followed recommended management practices. As a consequence, in these farms, HLB incidence increased dramatically in 2007-2008, mainly in orchards with trees up to 6 years of age. These farms have served as sources of contamination, making it very challenging and costly for their close neighbours to manage the disease. For example, in one farm of 240,000 four-year old irrigated trees, in some blocks bordering a highly infected farm, where no control measure were applied, the disease increased from 0.03% in 2005 to 7.63% in 2008, in spite of constant removal of diseased trees and of around 20 insecticide applications per year (Lopes et al. 2008).

The impact of HLB on yield was recently quantified in Brazil (Bassanezi & Bassanezi 2008). In younger blocks the disease incidence and severity progress is faster than in older ones. The factors that support this are:

- more frequent and intensive new shoots in younger trees attract higher population of HLB psyllid vector that allows higher infection rates; and
- small canopy size leads to relative higher initial severity of symptoms and faster distribution of the pathogen into the tree.

The HLB incidence progress curves was well described by the Gompertz model [$y = \exp(-(-\ln(y_0)) \cdot \exp(-rG \cdot t))$] [9], where y is the proportion of symptomatic trees at time t (years), y_0 is the proportion of symptomatic trees at the first appearance of symptomatic trees, and rG is the annual rate of disease incidence progress. Disease incidence reached 50% ($y = 0.5$) in less than two years after the appearance of first symptomatic trees in 0-2 year old blocks, and in about ten years after the appearance of first symptomatic trees in blocks older than ten years. For trees in which the first symptoms occurred when they were 0-2 years old, it takes about two years for the HLB severity to reach 100% ($s = 1.0$), while it takes about 12 years for trees in which the first symptom onset occurred when they were older than 10 years. Disease incidence and severity estimated every year were used to estimate the total disease severity in the affected citrus block (S) every year by a discrete model $S_n = \sum (y_j - y_{j-1}) s_{n-j}$. $RY = \exp(-1.8 \cdot S)$, which describes the relationship between disease severity and fruit yield, to estimate the relative yield of the affected citrus block compared to yield of healthy citrus block (RY). With this approach Bassanezi & Bassanezi (2008) estimated RY in citrus blocks without any HLB control measures for each year, depending on the age of citrus trees at HLB symptom onset. By multiplying the estimated RY by expected yield of healthy groves for each year it was possible to estimate the impact of HLB on yield under no disease control. Without adoption of HLB control measures, citrus blocks infected up to five years old would have considerable yield reduction about two to four years after the onset of the first symptomatic trees. However, for older citrus blocks, the yield reduction would be significant five to ten years after the first symptoms. The model does not take into account effects of hedging and topping.

Impact on Nursery Production

Both *D. citri* and '*Ca. L. asiaticus*' have been shown to move with orange jasmine sold in Florida (Manjunath et al. 2008a, Ramadugu et al. 2008). As a consequence of the rules and requirements imposed by the Florida Citrus Health Response Plan, the number of citrus nurseries declined from 70 nurseries in 2000 to 35 in 2008 (Spann et al. 2008). Abiding by these new rules comes with a high price, and monumental risk for the nurseryman. Structures that meet requirements cost US \$77 to \$132 m⁻², and most are uninsurable. This results in the price for a nursery tree ranging from US \$8 to \$10 (Spann et al. 2008).

Cost of Extra Treatments - Orchards

Disease management. Examples of direct costs are production losses due to:

- costs associated with scouting and tree removal;
- direct production losses as a result of fewer trees in production;
- fruit drop on infected trees;
- costs associated with increased insecticide applications;
- costs associated with additional personnel; and
- costs associated with the growing or purchasing of nursery trees that are grown under insect-proof screenhouse and isolation requirements.

Examples of indirect costs are costs associated with:

- the impact of chemicals on non-target organisms;
- distraction of management and personnel from their core duties; and
- potential business risks due to regulatory actions, and pesticide issues.

From an economic viewpoint, the two main consequences of citrus greening are increased tree mortality, and increased costs of production (Morris et al. 2008). It is estimated in Florida, that post-HLB production costs have increased by approximately 40% compared to pre-HLB production costs (Irey et al. 2008a): see Table 2. Attempts to manage HLB in Florida are adding \$US 476/acre (inspection \$110, tree removal \$60, resets and planting \$56, psyllid control \$250/ acre) to the cost of production annually. Total production cost in Florida now is \$1376/acre (Snively, 2008). Patrick Gomes, National Co-ordinator of the Florida Citrus Response Program, estimated that pest management costs have increased by US \$620/ha and scouting costs by US \$124-148/ha since the advent of HLB (Gomez 2008). Attempts to manage HLB in Brazil are adding \$US 561/acre to the cost of production annually (Monteiro 2008).

Table 2. Estimated increases in costs (US \$) due to HLB at Southern Gardens, Florida (Irey et al. 2008a).

Item	pre-HLB	post-HLB
Scouting/ha	\$19	\$272
Spray materials/ha	\$198	\$346
Spray application/ha	\$247	\$667
Nursery tree	\$4-5	\$7-9

Cost of Extra Treatments – Nurseries and Budwood Scheme

The greatest challenge that the nursery industry in Florida had to overcome after HLB was detected in the state in 2005 was the loss of the Dundee and Immokalee budwood facilities that resulted in a critical shortage of budwood (Spann et al. 2008).

A finding of *D. citri* and/or HLB could result in the prohibition of movement of nursery trees and budwood from any nursery or budwood block in the PQA. If HLB becomes endemic in the region, tree movement to non-affected areas will be prohibited.^{25,26}

In Florida, it has been estimated that it would cost US \$2.5 million to build a nursery with the capacity to produce 175,000 trees annually to meet the requirements of the Florida Citrus Health Response Plan following the advent of canker, HLB and *D. citri* (The Ledger, 18 March 2006).

The following are minimum standards of the Florida Citrus Health Response Plan (http://www.aphis.usda.gov/plant_health/plant_pest_info/citrus/downloads/chrp.pdf) for citrus nurseries or budwood production in Florida (USDA, APHIS, PPQ.2006 Citrus Health Response Plan), following the establishment of HLB:

- Registration of all citrus nurseries and budwood facilities - includes a *Citrus Nursery/Budwood Facility Compliance Agreement* detailing the requirements for producing and moving citrus nursery stock, budwood and seed.
- Approval of citrus nursery and budwood facility sites at a minimum distance from commercial citrus groves, other citrus trees or rutaceous plants.
- Budwood facilities must be located at least 16 km away from commercial citrus production and away from concentrations of backyard citrus.
- Production of citrus nursery stock and budwood sources in approved structures. (The Florida Plan specifies 'structures constructed at a minimum with poly/polycarbonate covering or screened with a maximum screen size of 266 x 818 µm, designed to exclude psyllids, melon aphid and other aphids, leafminers or other pests. The structure should be sub-divided with additional interior walls and doors to further preclude or minimize internal insect movement should insects be detected in one part of the structure. Any structure must include double entryways with positive pressure air displacement. If cooling pads and fans are used they must be enclosed with insect resistant screen as described above. Adequate construction materials should be kept available on site in the event that the structure is damaged so that timely repairs can be made. Any damages that are detected must be immediately reported to the appropriate regulatory official.').
- An appropriate vector control prophylaxis program must be in place to facilitate control of potential exotic vectors in the structures. Also vector spray programs must be implemented in all outdoor nurseries during the transition period.
- Security and sanitation measures to prevent pest or disease introductions.
- Training and education of employees to recognise exotic diseases. Employer to maintain a log of training.
- Inspections to verify pest- and disease-freedom in citrus nurseries and budwood facilities. Florida requires 'citrus plants must be inspected for pests and diseases every 30 days by state regulatory inspectors and certified disease-free prior to transport. Any citrus nursery stock or budwood source tree found infected or exposed to citrus canker, citrus greening, ...psyllids, aphids or other common plant pests shall be subject to immediate quarantine action and will not be eligible for certification until treated as prescribed by the department and released from quarantine. Nursery environs shall be inspected in accordance with the Residential component of the CHRP. The presence of citrus canker or citrus greening in the environs that is determined to present a risk to the citrus nursery or budwood facility will result in an immediate quarantine of the nursery or facility until the risk can be mitigated. The approved structure containing citrus nursery stock and budwood material shall be inspected by trained nursery personnel on a weekly basis for the presence of exotic diseases and for the presence of any insects. Findings must be reported to appropriate regulatory officials. The structure's integrity will also be inspected every 30 days by the regulatory inspector to ensure that there are no holes or other damages that would compromise insect or disease exclusion. The inspector will also conduct a complete audit of the nursery or facility every quarter to verify compliance with production requirements'.

²⁵ See Citrus health Response Program Citrus Nursery and Budwood Protection Information at http://www.doacs.state.fl.us/pi/chrp/citrus_nursery.html

²⁶ See Technical Working Group Commercial Production and Movement of Citrus Nursery Stock from Florida to Non-citrus Producing States: Findings and Recommendations September 18-20, 2007, Gainesville, FL. http://www.aphis.usda.gov/plant_health/plant_pest_info/citrus/downloads/cns-twg-report.pdf

- Citrus budwood and seed certification. ‘Propagative material including budwood, air-layers, cuttings and all top-working material shall be from state-registered budwood source trees. Budwood shall be taken under the direct supervision of a witness authorized by the department. Budwood from each source tree shall be wrapped separately. Each bundle shall be labeled showing variety, the tree identification number, and number of buds counted or estimated. Seed from HLB-diseased trees should not be used.’
- All citrus budwood source trees shall be tested and indexed on a regular basis to ensure the disease-free status of citrus material.
- All citrus plants must remain free from arthropods and diseases of concern to maintain certification. The integrity of the structures must also be intact and the nursery or facility must be in compliance with production requirements in order to maintain certification.
- All citrus nursery stock and budwood moved from the facility must be accompanied by a state certificate documenting that the plant material meets state phytosanitary standards or the phytosanitary standards of the receiving state or country. This documentation must identify the citrus nursery or budwood facility site.

AUSTRALIAN CITRUS INDUSTRY

Potential Incursions of HLB and its psyllid vectors represents significant threats to citrus production in Australia, where annual production has averaged 615,000 tonnes over the last 5 years (from 2003-04 to 2007-08): see Fig. 1. Production has slightly decreased across all varieties (navels, Valencias, mandarins, lemons/limes and grapefruit) particularly since 2005-06²⁷: see Fig 2.

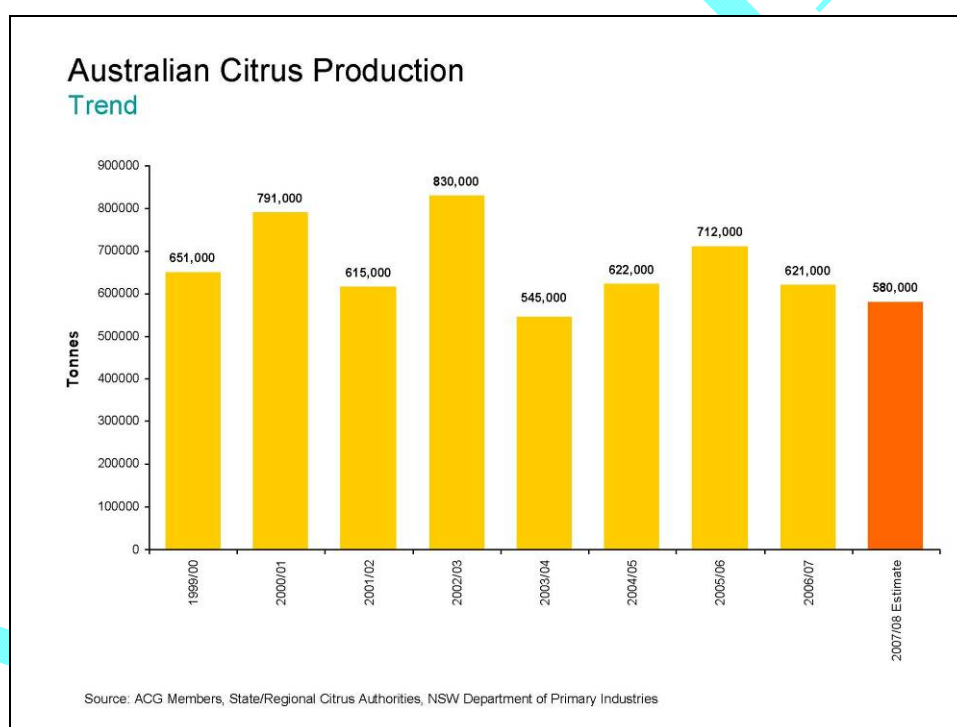


Figure 2. Australian citrus production (tonnes) 1999-2008: all fruit (Citrus Australia).

²⁷ Citrus Australia Limited — <http://www.australiancitrusgrowers.com.au/>

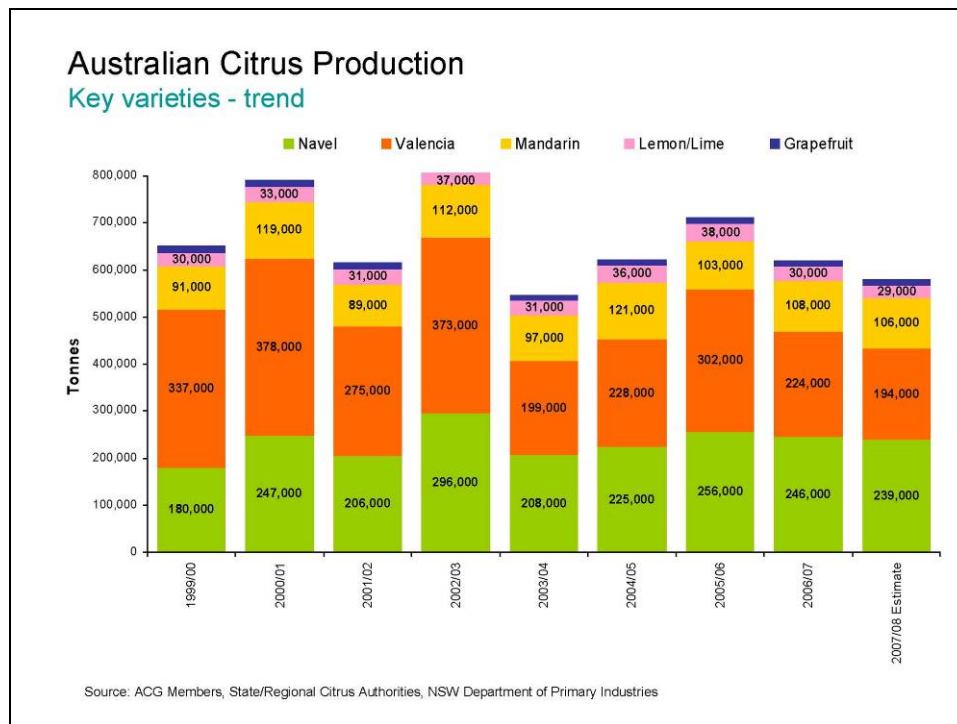


Figure 2. Australian citrus production (tonnes) 1999-2008: key varieties (Citrus Australia).

Australia is the fourth biggest citrus producing country in the southern hemisphere after Brazil, Argentina and South Africa; generating approximately 1% of global citrus production (Australian Citrus Growers 2004). There are about 2300 growers with plantings of 32,000 ha.

The major production areas are in the dry Riverland area of South Australia, the Murray Valley regions of Victoria and New South Wales, the Riverina area of New South Wales and the more humid Central Burnett region in Queensland (Fig. 3). Smaller citrus production exists in western and coastal New South Wales; Western Australia and the Northern Territory. All citrus at Emerald in Queensland was eradicated to eliminate an outbreak of citrus canker and replanting of commercial orchards has commenced.

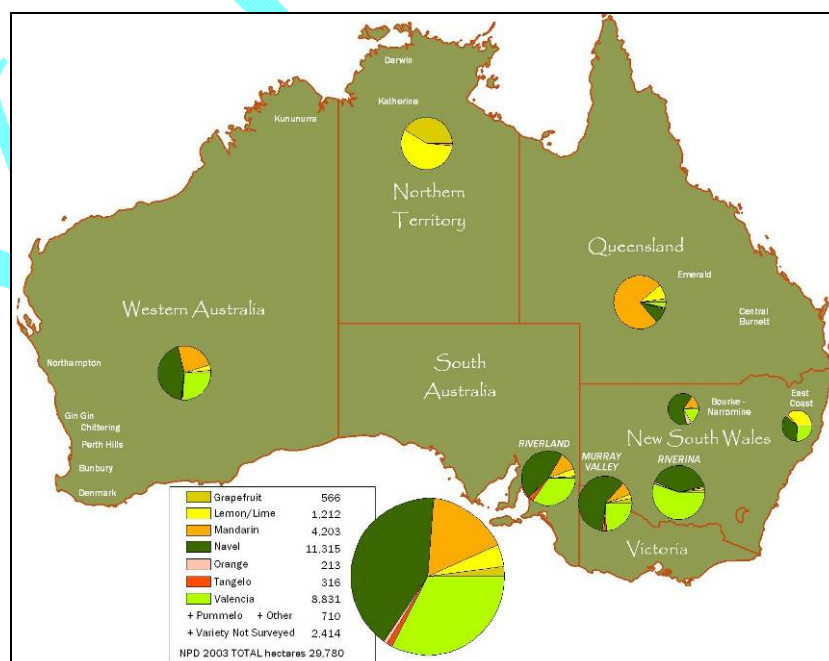


Figure 3. Distribution of citrus production in Australia (Citrus Australia).

Grown for both fresh fruits consumption and juice, the industry had an estimated gross value of production of AUD \$508 million in 2002 to 2003 and exports of approximately AUD \$201 million in 2002-2003 (Australian Bureau of Statistics 2004).

The proportion of production sold in fresh markets has increased, driven by changes in consumer preferences, as well as an increase in FCOJ imports. The majority of fresh fruit is sent direct to major supermarket chains or to key wholesalers in all Australian capital cities for distribution on the domestic market. Production of Valencia oranges in Australia has been decreasing since 1993-4, while the production of navel oranges has been gradually increasing for the last two decades (Australian Productivity Commission Report 20).

Mandarin production has increased from 30-35 kt in the early 1980s to 103 kt in 2005-6. 67% of mandarin production was sold in the domestic market in 2000, with Imperial mandarin the dominant variety. In 2000, 21% of mandarins produced in Queensland were supplied as fresh fruit to export markets (Australian Productivity Commission Report 20²⁸).

Citrus is Australia's largest fresh fruit exporting industry. Fresh citrus exports were valued at AUD \$173 million in 2006/7. Steadily increasing volumes of Australian citrus are exported to more than 48 countries, mainly Malaysia, Singapore, Hong Kong, Japan, the USA and Canada.

The volume of fresh citrus imports has remained relatively stable (Australian Productivity Commission Report 20, Australian Citrus Growers 2006) with 13,000 t of fresh oranges imported in 2005, principally from the USA, Spain, Israel and New Zealand. Most imports occur when citrus are not in season in Australia i.e., between December and April. The main citrus imports are oranges (principally navels) from the USA, followed by lemons and red grapefruit.

In addition to fresh fruit, significant tonnages of Australian Valencia oranges and some navel oranges, lemons and grapefruit are used for juice production, mainly as single strength (fresh juice). In 2005, 200,000 t of Australian oranges were processed with 600,000 t equivalent of orange juice concentrate imported, so that only 25% of all orange juice consumed in Australia was from Australian oranges.

National Plantings Database

The National Plantings Database project is a national levy funded project aimed at improving the record of planting statistics for the citrus industry. All major citrus growing areas have been aerial photographed, growers are being surveyed and the information compiled to generate a national view of citrus plantings in Australia. The database will prove invaluable during an outbreak of HLB and /or *D. citri* with the potential to generate a national view of citrus plantings in Australia. The database will provide details on the location, size and composition of plantings, information that is critical when defining the scope for surveillance activities and determining the extent of quarantine zones. The national plantings database project uses ArcView GIS software. ArcView's mapping capabilities would allow for timely, effective facilitation and coordination of surveillance and quarantine activities, in the event of an outbreak.

There is potential for early detection and mapping of HLB using techniques such as hyperspectral imaging (Ehsani et al. 2007).

²⁸ Productivity Commission. 2002. Citrus Growing and Processing. Inquiry Report No. 20. 270 pp.

IMPACT OF HLB ON AUSTRALIAN CITRUS INDUSTRY

In every place where the disease occurs, life expectancy of citrus is vastly reduced and production losses are significant (Halbert & Manjunath 2004). HLB, in the presence of the vector, has the potential to threaten the existence of a profitable citrus industry in Australia due to reduced production, unmarketable fruit and increased costs associated with control methods and reduced orchard life. Similarly the potential impact on industries relying on citrus production will be severe.

The impact will depend on where HLB is found, whether *D. citri* has established, how widespread the disease/vector has established and whether HLB and its vector can be eradicated or quarantined to an area e.g., the chance of eradication will be greater if a recent occurrence of HLB and /or *D. citri* is found on an offshore island in the Torres Strait or in a remote citrus growing locality e.g., Emerald or Kununurra, than if it is found in the Riverland or in a Sydney suburb.

The direct consequences of HLB and / or *D. citri* becoming established in certain regions of Australia can be considered in terms of impacts on:

- market access (international & interstate trade—immediate quarantine restrictions will disrupt bulk movement of fresh fruit);
- reduction in acreage;
- tree death;
- reductions in yield (more culls, infected fruit are smaller, premature fruit drop, infected fruit may have a bitter taste, fruit do not colour properly);
- increased costs for budwood and nursery trees (produced under screen and fewer nurseries);
- increased production costs related to²⁹
 - increased chemical costs for psyllid control,
 - changes to management practices e.g., increased planting density; the cycle of planting new trees in an orchard may have to be shortened to every 10 years,
 - rogueing,
 - scouting,
 - increased need for re-plants,
 - post harvest disinfestations;
- disruption of current integrated pest management that will lead to problems with pests currently under control; and
- fruit quality/yield and market prices.

As an example of the perceived seriousness of HLB to a citrus industry, the Citrus Research Board of California is coordinating that industry's multi-pronged effort against the psyllid, *D. citri*, a task that the Executive Officer of CRB considers could require \$1.5 million annually. The Californian plan includes a public outreach campaign aimed at helping urban residents spot the pest in their yards and ramped up field efforts by industry to augment the work of the US Department of Agriculture and the California Department of Food and Agriculture.

Postharvest Impacts

Bulk shipments of fruit (with or without leaves attached) moving between areas could be a means of dispersal of the vector³⁰ (see for example Halbert et al. 2008). There are also reports from Brazil of *D. citri* being carried in empty fruit trucks. Movement restrictions on bulk fruit prior to packing will need to be put in place to prevent movement of *D. citri* between citrus growing areas or interstate.

²⁹ see http://www.flcitrusmutual.com/content/docs/issues/canker/SG_presentation.pdf.

³⁰ California was concerned about bulk shipments of fruit from Mexico where *D. citri* now occurs: <http://www.capitalpress.info>; 23 February 2007.

Care will be needed to ensure that insecticide applications for psyllid control do not result in residues that exceed the MRLs of countries importing Australian citrus fruits, and for domestic markets. A listing of citrus export MRLs was provided through the Horticulture Australia project FR04024 'Residue risk analysis and development of risk management options for major export markets for certain fruits'. MRLs for citrus are listed on the Citrus Australia's website but standards are subject to change³¹.

Assessments of the environmental and health effects of some of the insecticides used for control of *D. citi* in Florida were recently prepared by the US Department of Agriculture (Poe 2007)³².

Impacts on Allied Industries

A full economic assessment of the impact on citrus, nursery and allied industries is required and should be completed before an incursion occurs and take into account Davidson et al. (2004)³³.

Estimating Impact on Trade and Market Access Implications

International trade is unlikely to be affected by incursions of HLB and its vectors unless seed transmission of HLB pathogens is confirmed. Fruit is exported from South Africa, where HLB occurs, to Europe and the USA. Florida, where HLB has been present since 2005, has continued to export grapefruit to Japan. HLB does not occur in Europe or in the main citrus producing regions of Japan.

Requirements for the domestic movement of fruit in bulk bins and cartons will need to be reviewed and regulations imposed to ensure that psyllids are not transported from quarantined to HLB and psyllid-free areas.

Trade of *Citrus*, *Murraya*, *Bergera* and *Clausena* nursery stock, budwood and fresh leaves (e.g., leaves of *C. hystrix* and *B. koenigii*³⁴) from quarantined areas will need to be prohibited.

If seed transmission of HLB pathogens is confirmed, AQIS will need to prohibit importation of citrus rootstock seed and seed of citrus relatives from countries where HLB occurs. BA and AQIS will need to consider prohibiting imports of fresh fruit containing seeds, if these fruit are from countries where HLB occurs.

AUSTRALIAN CITRUS BUDWOOD SCHEME

Auscitrus is the trading name of the Australian Citrus Propagation Association Incorporated (ACP), a national 'not for profit' industry organisation comprising citrus growers and nurserymen from each State. Auscitrus is responsible for supply of citrus budwood and seed in Australia, and operates under a Deed of Licence with the NSW Department of Primary Industries (NSW DPI) at research institutes at Dareton and Camden. Close links are maintained with state-based seed supply schemes in Queensland and South Australia.

³¹ http://www.australiancitrusgrowers.com/aspdev/marketing/export/mrl_listing.asp

³² http://www.aphis.usda.gov/plant_health/ea/downloads/citrusgreening-ea-10-07.pdf.

³³ Davidson A, Elliston L, King J-A, Brennan J. 2004. Contribution of Plant Industries to Regional Economies. ABARE Project Commissioned by Plant Health Australia.

³⁴ see: State of California Department of Food and Agriculture, Pest Advisory Advisory 21-2007 - http://www.co.san-diego.ca.us/reusable_components/images/awm/Docs/ipd_asian_citrus_psyllid.pdf.

Auscitrus responsibilities include:

- budwood and rootstock seed production and distribution;
- pathogen indexing and elimination;
- maintenance of virus free and pre-immunised foundation trees in insect proof screenhouses;
- importation of new citrus cultivars; and
- horticultural screening of new varieties.

Budwood source trees are located at the Agricultural Research and Advisory Station, Dareton, with a supplementary supply of new varieties located at Monash in South Australia, under the management of the South Australian Citrus Improvement Society (SACIS). Budwood of some varieties is also cut from indexed trees maintained at the NSW DDPI Research Station at Griffith,. New varieties released from post-entry quarantine undergo rapid nursery and field multiplication at Dareton. The Auscitrus repositories for virus free and pre-immunised clones are located in insect-proof screenhouses at the NSW DPI's Elizabeth Macarthur Agricultural Institute (EMAI) at Camden, with a field repository at Dareton. The total number of buds sold in 2006/7 was 488,033 down from previous years of 679,554 in 2005/6 and 830,445 in 2004/5, with an average of 722,755 buds sold per year over the last 5 years. In 2007, seed orders were 351 kgs compared to 433 kg in 2006 and 629 kg in 2005³⁵.

AUSTRALIAN CITRUS AND ORNAMENTAL NURSERY INDUSTRIES

The following information for Queensland was supplied by John McDonald, Nursery Industry Development Manager, Nursery & Garden Industry Queensland:

- The Queensland nursery industry is a significant horticultural producer and retailer with approximately 1200 growers and more than 1500 retailers across Queensland employing an estimated 6500 (FTE) people. The production sector is valued at \$451 million and is ranked third behind sugar and fruit & vegetables in contributing to the value of horticulture in Queensland. Nationally the industry is estimated to be worth \$5.5 billion and employs some 45,000 FTE in more than 20,000 small to medium sized businesses. Nursery production across Australia provides the starter crops for the estimated \$10 billion horticulture industry.
- The production sector of the industry in Queensland is located predominantly along the coastline of Queensland, between the Tweed River and Cairns, with pockets of producers situated in various inland locations (e.g., Toowoomba, Emerald, and Atherton Tablelands). The bulk of nursery production is undertaken in the south east corner of Queensland with an estimated 70% of all greenlife produced between Noosa and the NSW border and west to Toowoomba. The remaining 30%, or between \$100 to \$200 million, of nursery production occurs throughout regional Queensland generally hubbed around the major coastal centres from Bundaberg to Cairns.
- The nursery production sector in Queensland consists of a diverse range of crop lines and target markets underpinning the \$2.3 billion Queensland Horticultural industries including:

Production Nursery	Horticultural markets	Economic value
Container stock	Ornamental/urban horticulture	\$155 million retail value
Foliage plants	Interior-scapes	\$40 million industry
Seedling stock	Vegetable growers	\$800 million industry
Forestry stock	Plantation timber	\$200 million industry
Fruit and nut tree stock	Orchardist's (citrus, mango, etc)	\$540 million industry
Landscape stock	Domestic & commercial projects	\$470 million industry
Plug and tube stock	Cut flower	\$125 million industry
Revegetation stock	Farmers, government, landcare	\$5.5 million industry
Mine revegetation	Mine site rehabilitation	Value unknown
	Total Queensland Market Value	\$2.3 billion

³⁵http://www.auscitrus.com.au/files/Newsletter_-_Winter_2007.pdf.

- Greenlife retail outlets are located in almost every town and city in Queensland either as a dedicated Garden Centre or as an attached retail department in a hardware outlet or supermarket. Plant material is sourced from across Queensland and Australia to stock these outlets with plant movement up and down the major transport corridors occurring daily and in volume. This is also true for all other market channels with fruit tree, forestry, landscape and re-vegetation stock moved to growers and locations across Australia.
- A truly unregulated and disengaged market channel is the 'flea market' retail outlet with multiple sellers at most markets across Queensland. NGIQ estimates these operators to number close to 1000 businesses ranging from very small to those with large stock turnover rates and high profitability. Many of these operators grow greenlife on small land parcels (urban/peri-urban) and are bypassed by mainstream horticultural information channels (industry & government) due to the inability of peak bodies and government to locate them and the resistance of these operators to engage with the peak industry bodies.
- Accuracy of the industry data is important for industry biosecurity and to future planning, resource use and market access issues. At present this is lacking due to the limited ability of the industry (NGIQ) to undertake rigorous data gathering.
- The NGIQ has over the past 5–10 years identified an increase in the production and retailing of greenlife by a variety of professional, semi-professional and non-professional businesses and individuals throughout the state. This increase has coincided with the decrease of extension support and general government contact with producers and has resulted in a very poor and disjointed communication stream. This diversification of producers and the varied retail channels/markets used to distribute the product and the diverse end users of nursery crops has made the traditional communication methods outdated and ineffective.

NGIQ believes that it is essential 'to have a process, supported by legislation, that ensures those involved in the nursery industry are identified and address details are current'. The overview is as follows:

- All sellers of greenlife (plants), including those who grow greenlife and hold for sale must be listed on a database (retail, wholesale & production)
- **Exclude** landscapers, and builders and garden maintenance businesses who buy plants for incorporation directly into a landscape/building project or garden makeover or repair.
- Database details to include (separate details for each business site):
 - Name of business
 - Identify either retail, wholesale or production
 - Retail to identify type (garden centre, hardware, supermarket, etc)
 - Production to identify crop type (seedling, shrubs, fruit, etc)
 - Production to identify market channel (retail, markets, farmer, etc)
 - Name of principle/owner
 - Address & Lot number where business is located
 - Land area of business (m² or ha)
 - Mailing address
 - Telephone, facsimile number, email and website
 - Estimated annual turnover
- A registration number is issued for each site and must be displayed at the business or point of sale.
- NGIQ would undertake on behalf of stakeholders (industry & government) to administer the database.
- NGIQ would communicate to industry on behalf of stakeholders.
- An annual administration fee of approximately \$75 would be charged per registration.
- State legislation would be required to ensure the mandatory requirement of industry participation.

NGIQ considers the above to be a proactive strategic state based initiative that has the potential to eventually align to a national whole of industry strategy. Industry would require government support across all states and territories to achieve this expanded strategy in the future.

IMPACT OF HLB ON AUSCITRUS BUDWOOD SCHEME AND THE CITRUS AND ORNAMENTAL NURSERY INDUSTRIES

Should HLB become established in Australia, the following restrictions (as outlined in the Florida Citrus Health Response Plan) would have to be considered³⁶:

- Registration of all citrus nurseries and budwood facilities - including a *Citrus Nursery/Budwood Facility Compliance Agreement* detailing the requirements for producing and moving citrus nursery stock, budwood and seed.
- Approval of citrus nursery and budwood facility sites at a minimum distance from commercial citrus groves, other citrus trees or Rutaceous plants.
- Budwood facilities must be located at least 16 km away from commercial citrus production and away from concentrations of backyard citrus.
- Production of citrus nursery stock and budwood sources in approved structures. (The Florida Plan specifies 'structures constructed at a minimum with poly/polycarbonate covering or screened with a maximum screen size of 266 x 818 µm, designed to exclude psyllids, melon aphid and other aphids, leafminers or other pests. The structure should be sub-divided with additional interior walls and doors to further preclude or minimize internal insect movement should insects be detected in one part of the structure. Any structure must include double entryways with positive pressure air displacement. If cooling pads and fans are used they must be enclosed with insect resistant screen as described above. Adequate construction materials should be kept available on site in the event that the structure is damaged so that timely repairs can be made. Any damages that are detected must be immediately reported to the appropriate regulatory official.').
- An appropriate vector control prophylaxis program must be in place to facilitate control of psyllids in the structures. Also vector spray programs must be implemented in all outdoor nurseries during the transition period.
- Security and sanitation measures to prevent pest or disease introductions.
- Training and education of employees to recognise HLB and its vectors. Employer to maintain a log of training.
- Inspections to verify pest- and disease-freedom in citrus nurseries and budwood facilities. Florida requires 'citrus plants must be inspected for pests and diseases every 30 days by state regulatory inspectors and certified disease-free prior to transport. Any citrus nursery stock or budwood source tree found infected or exposed to citrus canker, citrus greening, ...psyllids, aphids or other common plant pests shall be subject to immediate quarantine action and will not be eligible for certification until treated as prescribed by the department and released from quarantine. Nursery environs shall be inspected in accordance with the Residential component of the CHRP. The presence of citrus canker or citrus greening in the environs that is determined to present a risk to the citrus nursery or budwood facility will result in an immediate quarantine of the nursery or facility until the risk can be mitigated. The approved structure containing citrus nursery stock and budwood material shall be inspected by trained nursery personnel on a weekly basis for the presence of exotic diseases and for the presence of any insects. Findings must be reported to appropriate regulatory officials. The structure's integrity will also be inspected every 30 days by the regulatory inspector to ensure that there are no holes or other damages that would compromise insect or disease exclusion. The inspector will also conduct a complete audit of the nursery or facility every quarter to verify compliance with production requirements'.
- Citrus budwood and seed certification. 'Propagative material including budwood, air-layers, cuttings and all top-working material shall be from registered budwood source trees. Budwood from each source tree shall be wrapped separately. Each bundle shall be labeled showing variety, the tree identification number, and number of buds counted or estimated. Seed from HLB-diseased trees should not be used. All citrus budwood

³⁶ Minimum standards of the Florida Citrus Health Response Plan

(http://www.aphis.usda.gov/plant_health/plant_pest_info/citrus/downloads/chrp.pdf) for citrus nurseries or budwood production in Florida (USDA, APHIS, PPQ.2006 Citrus Health Response Plan)

source trees shall be tested and indexed on a regular basis to ensure the disease-free status of citrus material. All citrus plants must remain free from arthropods and diseases of concern to maintain certification. The integrity of the structures must also be intact and the nursery or facility must be in compliance with production requirements in order to maintain certification. All citrus nursery stock and budwood moved from the facility must be accompanied by a state certificate documenting that the plant material meets state phytosanitary standards or the phytosanitary standards of the receiving state. This documentation must identify the citrus nursery or budwood facility site³⁷.

These minimum standards will impose a considerable impost on nurserymen and ultimately on growers from the increased cost of nursery production. Some nurserymen will go out of business, as the costs of improved infrastructure will be too great. The effect on the Australian citrus budwood scheme operated by Auscitrus, would be equally catastrophic if the outbreak occurred in Sunraysia and would involve significant costs in relocating to an area at a distance from citrus production and providing psyllid-free screenhouses for the production of all budwood and nursery stock.

Sales of orange jasmine will be affected by an incursion of *D. citri* alone or in combination with one or more of the HLB pathogens. Depending on the distributions of the vector and disease it will be necessary to:

- ban trade and movement of *M. paniculata* (*sensu lato*) between and within states; and
- eradicate existing *M. paniculata* (*sensu lato*) plants (growing naturally, or in nurseries, home gardens, parks and elsewhere) as occurs in São Paulo, Brazil (see Lopes et al. 2008).

IMPACT ON HOME GARDENS

Citrus is commonly grown by home gardeners and an incursion of HLB and *D. citri*, given the damage potential, climate suitability, experience in other countries and likely presence of alternative host plants such as *Murraya*, will place home grown host plants at serious risk. They will also provide sources of inoculum for further spread. In areas where the pathogen and the vector become established, it is probable that owners will find it necessary to undertake regular and ongoing control measures, such as the routine application of insecticides, with consequent economic and environmental effects, to have a chance of maintaining healthy trees over time. In a closely settled environment where a co-ordinated approach to control is unlikely and varied levels of husbandry can be expected, home garden trees can be expected to be subjected to regular challenge by infective psyllids.

IMPACT ON NATIVE ECOSYSTEMS

The chance of successful establishment of *D. citri* following an incursion could be high, given the distributions of hosts of *D. citri* in northern Australia, particularly *Citrus* species and varieties, and forms of *M. paniculata*, in native or naturalised vegetation, orchards, home gardens, parks and nurseries. Indigenous citrus is continuous around the Australian coastline — *Glycosmis* spp. in thickets in northern Australia (Armstrong 1975, Sykes 1999), and *C. australis*, *C. australasica*, *C. garrawayi* and *C. inodora* in rainforests along the east coast (Armstrong 1975, Sykes 1997), *C. gracilis* in the Northern Territory and *C. glauca* distributed inland from north of Emerald, through central Queensland, and New South Wales to the Flinders Ranges (Sykes 1999). *M. paniculata* var. *exotica* is common ornamental gardens and wild plants, regarded as *M. paniculata* var. *ovatifoliolata* Engl., despite variations in phenotypes and phytochemistry (Brophy et al. 1994, Mabberley 1998), occur in coastal and sub-coastal monsoon vine-thickets on stabilised dunes or lateritic ledges above the beach; vine-thickets on rock outcrops in open woodland in Western Australia, Northern Territory and Queensland (Brophy et al. 1994, Mabberley 1998).

³⁷ See also http://www.aphis.usda.gov/plant_health/plant_pest_info/citrus/downloads/cns-twg-report.pdf.

Appendices V and VI list known host plants for ‘*Ca. Liberibacter* spp.’ and *D. citri* and include some Australian native citrus species. *C. australis* and *C. glauca* have been recorded in overseas studies as hosts for *D. citri*. *C. australasica* has been recorded in overseas studies as a host for HLB and *D. citri*. An incursion could be expected to have some level of negative effect on these species and the other native citrus, *C. inodora*, *C. gracilis* and *C. garrawayi* may well be affected, but are not yet recorded as hosts. These species and other alternative hosts need to be targeted during control measures and some level of negative effect on the environment from insecticide application or plant removal could be expected.

The potential of these plants as hosts of *D. citri* will vary with phenotype, flush phenology and also the environments in which they grow. Care will be required to ensure that any eradication campaign does not lead to the loss of rare and endangered indigenous Australian species of *Citrus* (most of the above species).

RETAIL STORES AND WEEKEND MARKETS

In Florida the Asiatic citrus psyllid was distributed throughout the state primarily through retail trade in orange jasmine sold as ornamental plants (Halbert et al. 2008). IPsyllids are generally hard to find in large commercial nurseries in Florida, but appear to be very common in retail nurseries (Manjunath et al. 2008a). Movement of ‘*Ca. L. asiaticus*’ infected plants (*Citrus* spp. and *Murraya* spp.) and psyllids in the state by retail stores may have played a significant role in rapid wide distribution of the HLB. ‘Psyllids were found thriving in several retail stores. Temperature and other environmental conditions in garden stores, availability of continuous new flush for psyllid feeding, inadequate pesticide treatment, and lack of exposure to severe winter conditions may aid in better survival of both psyllids and *Ca. L. asiaticus* throughout the year in such an environment. Under these conditions, plants may be infected but asymptomatic, with a long latency period. These plants moved to other states, and may serve as sources of inocula in new locations’ (Manjunath et al. 2008a, Ramadugu et al. 2008).

An unregulated and disengaged market channel is the ‘flea market’ retail outlet with multiple sellers at most markets across Australia. Nursery & Garden Industry Queensland (NGIQ) estimates these operators in Queensland to number close to 1000 businesses ranging from very small to those with large stock turnover rates and high profitability. Many of these operators grow greenlife on small land parcels (urban/peri-urban) and are bypassed by mainstream horticultural information channels (industry & government) due to the inability of peak bodies and government to locate them and the resistance of these operators to engage with the peak industry bodies. These operators will be a considerable threat to any eradication efforts.

E-commerce

The Animal and Plant Health Inspection Service (APHIS) of the United States Department of Agriculture, in conjunction with the Center for Integrated Plant Management (Northern Carolina University) has developed an agricultural internet monitoring system (AIMS) for assisting APHIS to locate and regulate online sales of regulated organisms and identify potential commercial pathways for invasive species into the USA.

AIMS is an intranet-based website which integrates webcrawler software with locally developed data management software. It allows APHIS to semi-automate the process of:

- Locating internet sites selling AHPIS-regulated articles using spidering software which scans for specific key words (e.g., plant names) and applies filters to identify only those sites selling these materials. Information on these sites is then downloaded into a database to assist APHIS officers with extension and compliance activities.

- Evaluating sites to assess risk, which includes determining if the site has a valid permit – the permit database is integrated into the AIMS system. Emailing suspect sites requesting the offending articles to be removed and providing information about relevant legislation and prohibited and other invasive species. Archiving and retrieving reports and processing violations. AIMS currently tracks US based internet sites for around 600 regulated species.

In Australia, the Cooperative Research Centre for National Plant Biosecurity (CRCNPB) is developing an internet surveillance system for prohibited plants and commodities. The project ‘Software development and support for invasive species internet monitoring in Australia’ is a collaborative effort between the CRCNPB, Department of Agriculture and Food – West Australia (DAFWA) and the Centre for Integrated Pest Management (CIPM), North Carolina State University. The aim of this project is to develop a rapid and customised internet web crawler which will detect organisations who intend selling invasive species (via the internet) that are prohibited in Australia. This could be extended to include trade in any species regulated nationally or between states.

The Californian HLB Incursion Management Plan proposed implementation of regulations to control sales via E-commerce—with online monitoring of trade partially based on pop-up alerts when someone from California attempts to purchase rutaceous plants from other American states.

PHYTOSANITARY CONDITIONS ON CITRUS IMPORTS

Agricultural commodities imported into Australia may be subject to quarantine inspections and specific quarantine procedures/ treatments on arrival, carried out by Australian Quarantine and Inspection Service (AQIS) officers. ICON is the AQIS import conditions database. It sets out phytosanitary conditions for imports of *Citrus* (seed, nursery stock, fresh fruit and leaves/ peel/ pomander) and citrus relatives (e.g., fresh wampee, *Cl. lansium*, fruit, and curry leaves, *B. koenigii*³⁸). It is publicly accessible at www.aqis.gov.au/icon. It must be updated in light of recent changes to the systematics and nomenclature of the Rutaceae.

Post-entry quarantine requirements for *Citrus* and *Citrus* relatives need to be revised; particularly hosts of HLB. ICON also needs to be routinely updated as new hosts of HLB are reported, some with improvements in technology, others through new observations. As a precaution species of *Bergera* and *Clausena* that have not been confirmed as hosts to date should be prohibited, as detection of the HLB pathogens in these genera, and in *Murraya*, has been problematic (see Appendix V). All host plants of ‘*Ca. Liberibacter* spp.’ should be treated identically with commercial *Citrus* spp. in relation to post-entry quarantine requirements for imported nursery stock, budwood or cuttings. Appendix V list known host plants for ‘*Ca. Liberibacter* spp.’.

There is a report of seed transmission of liberibacter in citrus (Tirtiwidjaja 1981), but this has not been substantiated and there is no report of seed transmission in *Murraya* or any other citrus relative. However, seed transmission (as high as 53%) of ‘*Ca. L. asiaticus*’ was recently reported for dodder and periwinkle (Zhou et al. 2008a). Over 80% of the periwinkle plants germinated from the infected seeds showed initial HLB symptoms of vein yellowing and leaf yellowing but only when they were stressed by nutrient deficiency. The disease progressed slowly and did not cause plant death and all symptomatic plants became asymptomatic after the stress was removed (Zhou et al. 2008a). Sagaram et al. (2008), using PCR, did not detect ‘*Ca. L. asiaticus*’ in the endosperm and embryo of citrus seed. In the October 2007 Environmental Assessment Final Rule for Movement of Commercially packed Citrus Fruit from the Citrus Canker Quarantine Areas under IV Environmental Impacts it states ‘we have received reports of preliminary scientific evidence indicating that

³⁸ see: State of California Department of Food and Agriculture, Pest Advisory Advisory 21-2007 - http://www.co.san-diego.ca.us/reusable_components/images/awm/Docs/ipd_asian_citrus_psyllid.pdf.

when seedlings are generated from seed that is taken from plants infected with citrus greening, a small percentage of those seedlings are themselves infected with citrus greening. In response to this and to be abundantly cautious, APHIS has amended the Federal Order for citrus greening to prohibit movement of seed for planting from areas quarantined for citrus greening³⁹.

Fresh and frozen citrus leaves are prohibited from entry because these can carry serious pathogens of quarantine concern to Australia, including citrus canker. However, fresh kaffir lime leaves are permitted from the USA, where some states now have *D. citri* and Florida and Louisiana have HLB. Approvals to import leaves of *Citrus* and *Citrus* relatives need to be constantly reviewed in light of the recent detections of *D. citri* in Papua New Guinea (Davis et al. 2005) and Guam (Poe 2007, Poe & Shea 2007) and California (see Federal Domestic Quarantine Order: Citrus Greening Disease (CG) and Asian Citrus Psyllid (Acp) October 1, 2008³⁹).

PATHWAYS AND INTERCEPTIONS

The Australian Quarantine Inspection Service (AQIS) regards HLB as a serious threat to Australian citriculture, particularly from illegally introduced budwood or cuttings (Weinert et al. 2004), which could originate from any country with HLB. Indeed, recent interest in new varieties may have increased the risk of illegal introduction of budwood from countries such as South Africa and Florida, as well as Asia. There is a risk of the vectors, with or without the pathogen, entering Australia through human migration, travel (on yachts, boats and aircraft) and trade on plants or plant material, particularly via the Torres Strait (Brown 1998).

Pathway analyses conducted by the Office of the Chief Plant Protection Officer (Evans & Dempsey 2000, Naumann 2002) indicated that illegally imported citrus fruit, leaves and propagating material arriving in mail or carried by travellers entering Australia represent the highest risk pathway for introducing HLB and/or *D. citri*.

The authors of this incursion management plan consider that the risk of the pathogen or its vectors being introduced with commercially packed fruit that has been sorted, dipped, waxed and graded and packed in commercial packing houses is negligible, but that legally introduced fresh leaves may still represent a risk (see below). Transmission of the pathogen at low levels by *Citrus* seeds was reported by Tirtawidjaja (1981), but this has not confirmed (see section on seed transmission). However, preliminary scientific evidence from Florida indicating that when seedlings are generated from seed that is taken from plants infected with HLB, a small percentage of those seedlings are themselves infected, led APHIS to amend the Federal Order for HLB to prohibit movement of seed for planting from areas quarantined for HLB⁴⁰.

The most likely pathways are:

- illegal introductions of budwood from South Africa, Brazil, Asia or Florida by growers seeking commercial gain over other growers;
- householders illegally importing budwood or cuttings from trees owned by friends or relatives in countries where HLB occurs;
- legal importation of infested or infected material that has been inadequately treated and inspected (as in recent introductions of fresh *B. koenigii* leaves to California from Hawaii), or tested;

³⁹ https://www.wpdn.org/common/news_events/citrus_greening/FO%20final%20ACP%20in%20San%20Diego%20and%20CG%20in%20LA%2010-1-08%20OGC%20cleared.pdf

⁴⁰ October 2007 Environmental Assessment Final Rule for Movement of Commercially packed Citrus Fruit from the Citrus Canker Quarantine Areas under IV Environmental Impacts.

- passive transport of adult psyllids, which are strongly attracted to light, in commercial and military aircraft (the latter being a possible explanation for the recent detection of *D. citri* in Guam);
- air movements (e.g., cyclonic and jet streams) carrying psyllids from the Indonesian Archipelago, and New Guinea;
- movement of people carrying citrus fruits and other plant material across the Torres Strait from Papua New Guinea, principally by sea;
- unregulated landings of boats carrying citrus from other areas to the north of Australia; and
- agri-terrorism.

Bray & Sands (1987) considered that the close proximity of islands to the north and movement by international aircraft provide the principal vehicles for exotic insects entering Australia. In particular, they considered that the northern islands may act as 'stepping stones' for arthropods to cross the 170 km Torres Strait from Papua New Guinea. They noted that Australia's quarantine precautions, including the spraying of all international aircraft, and regular trapping for the most serious agricultural pests, minimise the chances of entry by exotic insects, but added that little can be done to exclude migratory species or those that enter by island hopping.

Halbert & Manjunath (2004) noted several interceptions of *D. citri* in the Caribbean Basin within five years of the psyllid being recorded in Florida in 1998. They assumed that this movement was related to cargo. They attributed entry of the psyllid into Florida through two likely scenarios:

- natural and gradual spread from South America, where the psyllid has been present since the 1940s (Halbert & Núñez 2004); and
- entry directly from Asia.

Records of interceptions of non-indigenous plant pests at US ports of entry and border crossing over a 17-year period from 1984 were reported, in a comprehensive review, by McCullough et al. (2006). Species of 'Homoptera'⁴¹ were the most commonly (36.8%) intercepted insects. According to Halbert & Manjunath (2004) the USDA/APHIS/PPQ database there were 170 recorded interceptions of live *D. citri*, and another 73 for *Diaphorina* spp. (many probably for *D. citri*) on rutaceous plants, from Asian countries at ports in the United States of America between 1985 and November 2003. In most cases, one or two specimens were found, but an interception in Des Plaines, Illinois, comprised 46 live *D. citri* from India (Halbert & Manjunath 1984). In most cases, these insects were intercepted on curry leaf (*B. koenigii*), but infested *Murraya* (*sensu stricto*) and *Citrus* plants were also observed. The interception reports for the most part reflected the known distribution of *D. citri*. More recent interceptions occurred in 2007 and 2008 when live psyllids were detected in shipments of fresh *B. koenigii* leaves exported legally with certification from Hawaii to California (Wilkinson 2007, Filippini 2008). Shipments of leaves from Hawaii to California are now prohibited (Filippini 2008). Further introductions of *D. citri* came in to California from Hawaii on non-host herb shipments of malungai and sweet basil leaf in January 2009 (see page 14).

In Australia, AQIS maintains a database that includes records of commodities seized from airline passengers (Airport Management System) and material found in mail articles (Seizure Database). Confiscated items suspected of carrying pests and diseases are sent for diagnosis to determine the quarantine status of the intercepted material. The Pest and Disease Information Database (PDI), maintained by Biosecurity Australia, records the seizures of illegal plant material that are found to harbour pests and diseases. The majority of citrus interceptions were of fruit and leaves carried by passengers on flights from Southeast Asia, with a small number originating from Europe and the

⁴¹ The taxon Homoptera is invalid: see Gullan PJ. 1999. Why the taxon Homoptera does not exist. *Entomologica* 33: 101-104.

Middle East. There are no records of interception of the HLB pathogens, or of the vectors of the disease, in the AQIS interceptions lists. However, interceptions in the USA, as summarised above, suggest that some may have occurred and could occur in the future.

The authors of this document consider the risk of airborne entry of *D. citri* from Indonesia, Papua New Guinea (and, in the future the Solomon Islands and other Pacific islands, should the psyllid spread to these locations), to be high and to increase with the inevitable spread of the psyllid through Papua New Guinea. This risk could be greatest when psyllid reaches the Milne Bay region on the southeast tip of the Papua New Guinea mainland and nearby islands.

Evidence to support this risk as high, can be gleaned from the introduction of the leucaena psyllid (*Heteropsylla cubana* Crawford [Hemiptera: Psyllidae]) into Australia. A pest of white leadtree (*Leucaena leucocephala* Lam.) de Wit [Fabales: Leguminosae]), an important pasture plant, it is believed to be native to the Caribbean (Mitchell & Waterhouse 1984). Bray & Sands (1987) hypothesised that it probably entered Australia in 1986 from the Western Pacific to the northeast of Queensland on air currents associated with severe tropical cyclone Winifred (Figs 4 & 5), in a region where cyclones occur annually (e.g., see Fig. 6). It was first recorded in Australia near Bowen in April 1986, shortly after a particularly severe cyclone in the area (Bray & Sands 1987). According to Bray & Sands (1987), personnel were well briefed to expect its arrival⁴². Within three months, the psyllid was recorded near Gympie, more than 10 km from a main road and some 830 km south of Bowen, and by mid-October was recorded in Brisbane (Bray & Sands 1987) (Fig. 7). Bray & Sands (1987) considered it most likely that the insect was dispersed throughout Queensland by wind currents. However, the life cycle of the psyllid suggests that such rapid dispersal may have been related to psyllid adults landing at several or more points along the Queensland coast between Townsville and Mackay. The life cycle, from egg to adult, is about 17 days. Adult females live for about 11 days. Average fecundity is about 400 eggs per female (Waterhouse & Norris 1987).

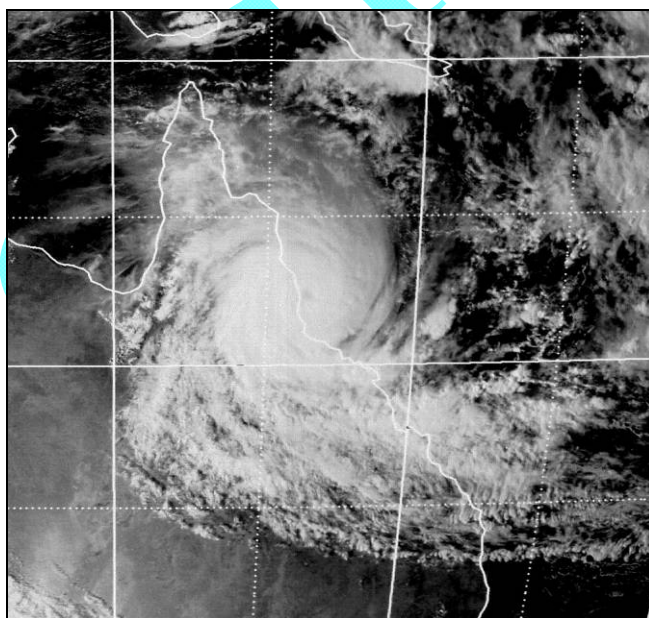


Figure 4. Cyclone Winifred as it crossed the Queensland coast on 1 February 1986 (photograph graciously supplied by Mike Willmott, Australian Bureau of Meteorology).

⁴² Although Bray & Sands (1987) stated that this was well documented, the authors of this incursion management plan could not locate the relevant documents.

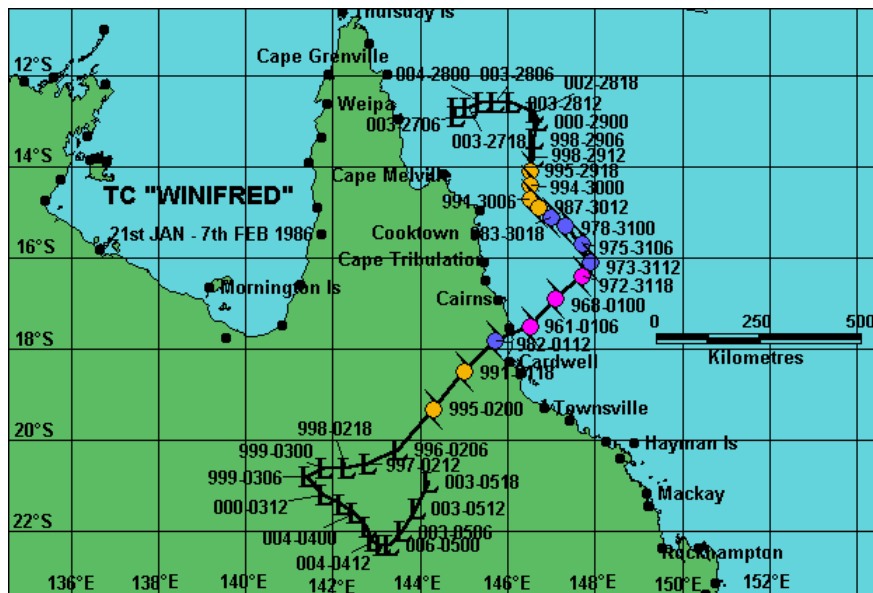


Figure 5. The path of cyclone Winifred in 1986 (Australian Bureau of Meteorology).

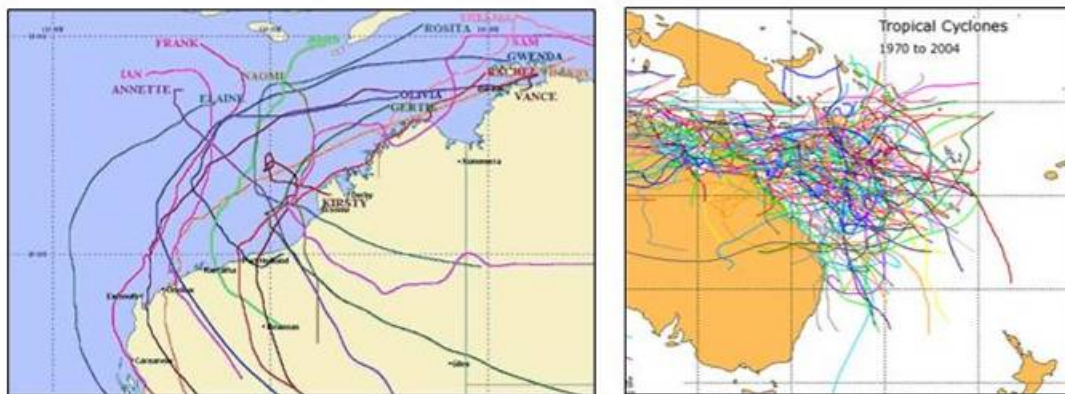


Figure 6. Tracks of tropical cyclones that occurred to the northwest, north and northeast of Australia between 1970 and 2004 (Australian Bureau of Meteorology).

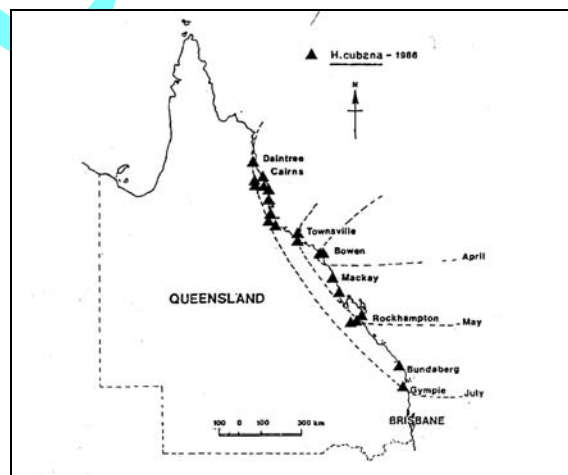


Figure 7. Dispersal of leucaena psyllid, *H. cubana*, within months of its entry into Queensland in 1996 (from Bray & Sands 1987).

The lettuce aphid (*Nasonovia ribisnigri* (Mosley) [Hemiptera: Aphididae]) is another example, albeit at a higher latitude than the preceding example, of an insect pest entering Australia in air streams. It was recorded in Tasmania in early 2004. Evidence suggested that it was carried to Tasmania from New Zealand in relatively uncommon easterly wind systems from 28 to 31 January 2004 (Stufkens et al. 2004⁴³). The potato psyllid, *Bactericera* (= *Paratrioza*) *cockerelli* (Šulc), the vector of a new liberibacter claimed to be the cause of a disease of Solanaceae (Hansen et al. 2008), was recently recorded in New Zealand (Liefting et al. 2008a). This psyllid is known to migrate trans-continentially every year across the United States (Liu et al. 2006). It may be possible for it to enter Australia from New Zealand in air-streams.

D. citri dispersal by wind over similar distances to those considered to have occurred for the leucaena psyllid, potato psyllids, and the lettuce aphid appears likely. However, the prevalence of host plants at potential points of ingress of wind-borne incursions into northern Australia would presumably be relatively lower than for the hosts of leucaena psyllid and lettuce aphid, and therefore the size *D. citri* populations at these sites would most probably be lower. However, the chance of successful establishment following an incursion would be high given the distributions of hosts of *D. citri* in northern Australia, particularly *Citrus* species and varieties, and *M. paniculata*, in native or naturalised vegetation, orchards, home gardens, parks and nurseries. However the suitability of hosts is influenced by species/cultivar, ambient temperature, nutrition, soil moisture, light (within shaded forests, on the edge of forests, under cloud or in sunny conditions), plant density (in sparsely spaced tropical forests or savannas, or in relatively dense monocultures), the nutritional value and the frequency of flush growth. See Appendix VI: Hosts of *D. citri*.

Sakamaki (2005) speculated that migration of the psyllid in the Okinawan Islands in southeast Japan is governed by seasonal winds. He considered it possible for the psyllid to migrate 470 km northwards to the large island of Kyushu over sea by riding lower jet airstreams (geostrophic movement) associated with summer monsoons. Gottwald et al. (2007) speculated that *D. citri* may have been carried some 90 to 145 km by wind over non-citrus growing regions in Florida. Although not conclusive, they considered that this long-distance movement may have been related to air masses during hurricanes or tropical storms.

Aubert (1987a) suggested that *D. citri* exhibits a *k*-type of self dispersal and that its common behaviour is to jump when disturbed, and then fly towards neighbouring targets, particularly HLB-affected trees or yellow traps. He reported observations that suggested possible medium to long distance transport by strong winds, since upsurges of *D. citri* had been recorded in open orchards without windbreak protection after typhoons, especially in the northern Philippines and along the southeast coast of China. Aubert (1987a) considered passive transport through 'advective winds' to be much more occasional. Based on studies reported by Aubert & Xia (1990) near Fuzhou in Fujian, China, Aubert (1990b) suggested that *D. citri* adults could to be taken into stratiform wind drifts and transported over distances ranging from 0.5 to 4 km. However, Aubert & Xia (1990) suggested 0.5 to 1 km. According to van den Berg & Deacon (1988), active host-seeking flight by *T. erytrae* can range up to 1.5 km.

Simple measurement of the distance from the presumed point of introduction to the advancing edge of the epidemic resulted in an estimated distance of spread of approximately 190 km, or about 19 km per year in Brazil (Gottwald et al. 2007). Long distance movement of HLB is likely by psyllid vectors and in this case could be related to movement of air masses carrying infected vectors during hurricane or tropical storms that have affected Florida recently over the void (from the initial point of discovery) to commercial areas (Gottwald et al. 2007, Halbert et al. 2008).

⁴³ <http://www.abc.net.au/rural/news/stories/s1179390.htm>
http://www.ausveg.com.au/docs/ausveg_industry_report.pdf

In Florida psyllids are generally hard to find in large commercial nurseries, but appear to be very common in retail nurseries. The results of Manjunath et al. (2008) and Ramadugu et al. (2008) suggest that movement of '*Ca. L. asiaticus*' infected plants and psyllids by retail stores may have played a significant role in rapid wide distribution of HLB.

The authors of this document recommend that:

- the Bureau of Meteorology, NAQS, and other relevant State and Commonwealth authorities collaborate to assess the risk of wind-borne incursions of *D. citri* and develop an 'early warning' system to alert State and Commonwealth agriculture and forestry departments, national parks, regional councils, and the nursery industry of a possible incursion;
- such assessments and warnings should take into account the natural and cultivated distributions of known hosts, particularly species of *Citrus* and *Murraya (sensu stricto)*, and of *B. koenigii* and *Cl. lansium*;
- such information should be incorporated into awareness programs;
- importation of fresh leaves of *Citrus* and of *B. koenigii* should be prohibited;
- responses to an incursion should be implemented less than one week after an incursion is detected; and
- application for permits for the use of insecticides be sought now.

THE VECTORS AND RELATED PSYLLOIDS

Diaphorina citri

Distribution of *D. citri*

D. citri occurs in the following regions and countries: in Asia, the Arabian Peninsula (Saudi Arabia and Yemen), and from Afghanistan through the Indian Subcontinent, Southeast Asia and East Asia (the Ryukyu Archipelago and Kyushu in Japan, in China, particularly Taiwan and the coastal provinces of Guangxi, Guangdong, Fujian and Zhejiang), the Philippines and through the Indonesian archipelago to north eastern Papua New Guinea; in Hawaii⁴⁴ and Guam; in the US States of Alabama, California, Florida, Georgia, Louisiana, Mississippi, South Carolina, and Texas, as well as the Commonwealth of Puerto Rico, Bahamas, Cayman Islands, Cuba, Jamaica, Dominican Republic, Guadeloupe, Venezuela, Brazil, Paraguay, Uruguay and Argentina; in the Indian Ocean, the Mascarenes (Mauritius and Réunion) (Aubert 1987c, Halbert & Manjunath 2004, Halbert & Núñez 2004, Weinert et al. 2004, OEPP/EPPO 2005a, Conant et al. 2007, Poe 2007, Poe & Shea 2007, US Federal Domestic Quarantine Order: Citrus Greening Disease (CG) and Asian Citrus Psyllid (Acp) October 1, 2008).

D. citri has been recorded in Australia. The record is based on a sample of 20 specimens collected at Stapleton (13° 11' S, 131° 01' E), Northern Territory, by GF Hill in 1915 (specimens in British Museum of Natural History). The host of these specimens is unknown, but it was most probably a species or hybrid of *Citrus*. It followed an incursion of citrus canker that is assumed to have been related to the introduction of *Citrus* from Asia to Darwin (then Palmerston: 12° 24', 130° 52'), about 100 km north of Stapleton, from Asia in the early 1900s (see Mertin 1952, Hollis 2004, Bellis et al. 2005). *D. citri* has not been recorded since and is assumed to have been eradicated by chance during the 1916-1922 eradication campaign for citrus canker, when all cultivated species and hybrids of *Citrus* trees north of 19°S were destroyed. It seems that the psyllid did not occur on naturalised or

⁴⁴ <http://hawaii.gov/hdoa/pi/ppc/2006-annual-report/asian-citrus-psyllid>

native *M. paniculata* L. var. *ovatifoliolata* Engl. (Bellis et al. 2005). Nor it seems did it occur on any introduced citrus relatives such as *B. koenigii*, *Clausena* spp. and *Murraya* spp., if they were present, or on *C. gracilis*, a species endemic to the northern region (north of about 13°S) of the Northern Territory and one that was not collected until 1971 (see Mabberley 1998).

Hosts of *D. citri*

Known hosts of *D. citri* are listed in Appendices VI. Information in this appendix is based on Halbert & Manjunath (2004), and other sources as cited, and has been modified to account for recent changes in the classification of *Citrus* and more broadly the Aurantioideae and the Rutaceae (see Appendix I). All known hosts of *D. citri* belong to the family Rutaceae, most within the Aurantioideae (Appendix VI): a record on jackfruit, *Artocarpus heterophyllus* Lamarck [Rosales: Moraceae], in India (Shivankar et al. 2000) is unquestionably erroneous, as demonstrated by Peña et al. (2006). The suitability of hosts is influenced by cultivar, ambient temperature, nutrition, soil moisture, light (within shaded forests, on the edge of forests, under cloud or in sunny conditions), plant density (in sparsely spaced tropical forests or savannas, or in relatively dense monocultures), the nutritional value and the frequency of flush growth, and local biotypes of the psyllid. Records should therefore be interpreted cautiously, more so given the likelihood that hosts have not been correctly identified. Young citrus trees that flush prolifically under ideal conditions are more suitable resources for the psyllid than older trees growing under identical conditions, and young and old trees grown under poor conditions. *M. paniculata* growing in a shaded forest will be a less suitable host than the same plant growing as an ornamental in a well-maintained garden.

Aubert (1988a) noted that *D. citri* in Asia, in contrast to *T. erytrae* in Africa, is not able to build up massively on a wide range of alternative rutaceous host trees or shrubs in forests.

Description of *D. citri*

A key to the genera of Psyllidae is given by Yang (1984). There is no key for the species of *Diaphorina* and identification is done by comparison with the following description by Yang (1984: on page 37). The genus is characterised by the following combination of characters:

- antennae usually very short (0.48 mm), with two apical short setae;
- aedeagus with first segment curved;
- genal cones flat and broad, not conical in outline and as long as or longer than broad, perrect, apices narrowly rounded or truncate; and
- forewing broad subapically, rounded at apex and narrow in basal half.

The European and Mediterranean Plant Protection Organization diagnostic standard for *D. citri* (OEPP/EPPO 2005a) contains the following description of the adults (including their genitalia), the egg and the nymphs of the psyllid are based on Yang (1984). Detailed illustrations of all stages are contained within Husain & Nath (1927) (Fig. 8) and Yang (1984). Less detailed illustrations of all stages are based on Catling (1970), and of wings and genitalia based on Yang (1984), are illustrated in OEPP/EPPO (2005a).

Adult. ‘General colour brown. Head slightly narrower than thorax. Vertex and genal cones greyish white. Antennae with two basal segments brown, third to eighth segments yellowish with apices of fourth, sixth, eighth and last two segments black. Eyes dark brown. Pronotum ribbon-like, rounded and weakly sinuate anteriorly with two impressed fovea on each lateral side. Mesoscutum brown to dark brown with black markings. Femora dark brown, tibiae and tarsi yellowish white to brown. Abdomen black dorsally and greenish white ventrally. Forewings hyaline with scattered maculation, 2.4 times as long as wide, narrow at base, broadest near apex, rounded apically, without distinct

pterostigma. Hind wings long and slender, 0.9 times as long as forewings, 3 times as long as wide. Length of body: male 1.53–1.66 mm; female 1.90–2.06 mm; length of antenna: 0.48 mm.⁴⁵

Egg. 'Light yellow when fresh, and turn bright orange (with two distinct red eye spots) at maturity; length 0.31 mm, width 0.15 mm.'⁴⁶

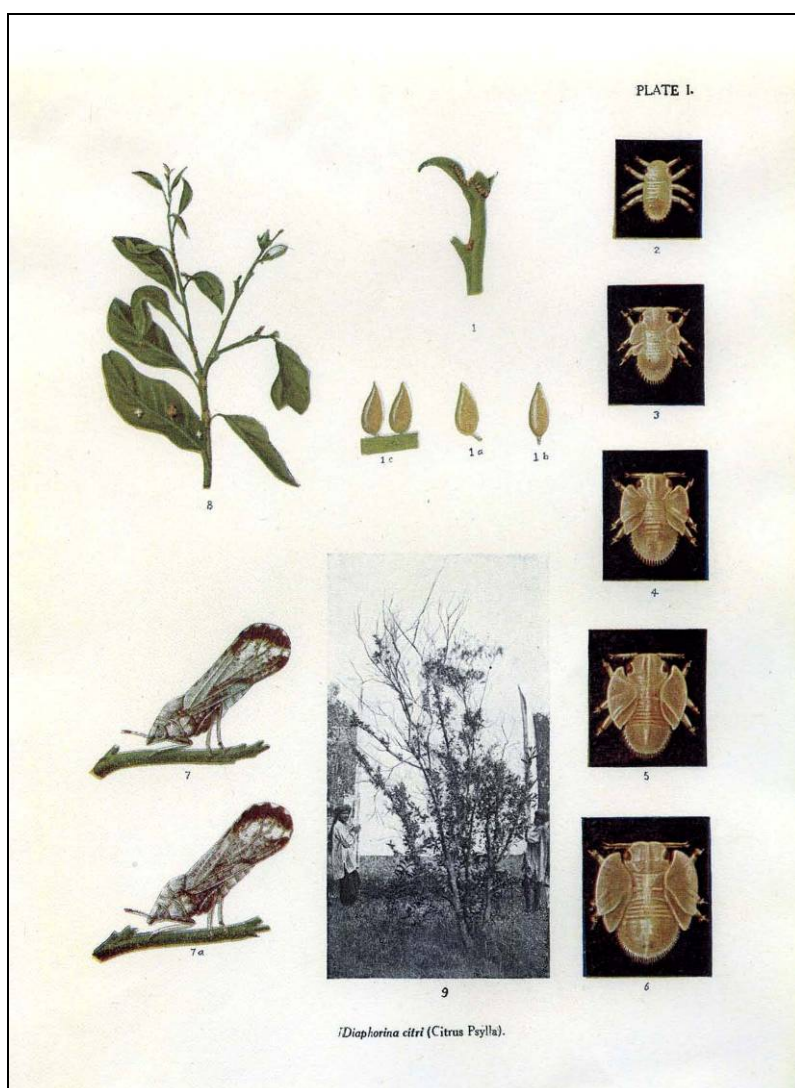


Figure 8. Plate I from Husain & Nath (1927), with illustrations of *D. citri* and its impact on citrus in the Punjab.

First instar nymph. 'General colour yellow, body elongate; antennae 2-segmented, relative length of each segment about 1:5, with 1 sensorium; legs segmented, tibiotarsus with 2 claws; abdomen margin with 7 pairs of setasetae. Length of body 0.33–0.35 mm; length of antennae 0.06 mm.'

Second instar nymph. 'General colour yellow; antennae 2-segmented, relative length of each segment about 1:2.8, with 1 sensorium; wing pads developed and separated; tibiotarsus with 1 golf club-shaped seta; abdomen with stripe-like sclerites at base and a large apical plate with margin with 7–8 pairs of setasetae. Length of body 0.49–0.53 mm; length of antennae 0.08 mm.'

⁴⁵ Abdomen colours are more variable and cannot be used to distinguish between adult males and females (Wenninger & Hall 2008, Yang Yueping, Guangdong Entomological Institute, pers. comm., 2007).

⁴⁶ Husain & Nath (1927) noted that 'The colour of a freshly laid egg is pale yellow, but as development of the embryo proceeds, the colour gradually turns orange. A short time before hatching two red spots—the eyes of the nymph—become visible. The egg shell is smooth and shining and no sculpturing of any description has been noticed'. 'The eggs are laid on the tender shoots in such large numbers as to impart to them a distinct orange colour.'

Third instar nymph. 'General colour yellow, antennae and abdomen somewhat dark; antennae 2-segmented, relative length of each segment about 1:4.5, with 2 sensoria on segment II; wing pads developed and overlapping; tibiotarsus with 1 golf-club-shaped seta; apical plate of abdomen margin with 15–17 pairs of sectasetae. Length of body 0.69–0.72 mm; length of antennae 0.14 mm.'

Fourth instar nymph. 'General colour from yellow to yellowish brown. Antennae 3-segmented, relative length of each segment about 1.5:1: 6, with 3 sensoria and two strong spines. Apical plate of abdomen margin with 27–30 pairs of sectasetae. Length of body: 0.98–1.05 mm; length of antenna: 0.19 mm.'

Fifth instar nymph. 'Body broadly oval, about 1.2 times as long as wide. General colour yellow to yellowish brown, third antennal segment black. All sclerites and wing pads vermiculated or punctuated. Legs relatively short, 4-segmented, tarsus with two claws, a funnel-shaped pulvillus and golf-club-shaped seta. Abdomen with strip-like sclerites at base and a large apical plate, margin with 25–29 pairs of sectasetae. Anal opening ventral, seta far away from apex of abdomen. Circum-anal pore ring composed of single row of slit-like pores, enclosing another ring of minute pores. Length of body: 1.45–1.58 mm; length of antenna: 0.27–0.30 mm.'

Key biological and morphological differences between *D. citri* and *T. erytreae* are summarised in Table 3, and illustrated in Fig. 11.



Figure 9. Adult *D. citri* (left) and ovipositing female: both on *M. paniculata* var. *exotica*, South China Agricultural University, Guangzhou (GAC Beattie).

For a positive diagnosis, the above characters should be present. A positive identification is possible on adult females and advanced larval instars. Microscope-slide preparation of stages of *D. citri* is strongly advised to allow proper identification (OEPP/EPPO 2005).

D. citri can be readily separated from most other species reported on citrus and its relatives by a distinct pattern on the forewings (Halbert & Manjunath 2004): distinct bars on the top and bottom resulting in the insects having the appearance of a flattened X-pattern when viewed from the side. *D. citri* can be separated from many of the Australian Psylloidea, specifically the Psyllidae subfamilies Spondyliaspidae and Triozidae, by its mottled wings, general 'squat' habitus and distinct wing venation. A few spondyliaspids and some triozids have patterned or mottled wings, but most species are distinctly elongate and have characteristic venation, i.e., trifurcating venation in the Triozidae (Hollis 2004).

D. citri in some aspects resembles Psyllinae species of *Acizzia*, which have a similar squat appearance and in which wing venation is often mottled. However, confusion is unlikely. In *Acizzia* the wing is ovate, with its widest point at about mid-length (rather than widest proximal to wing apex as in *D. citri*), wing vein Rs curves gradually to the costa and terminates well anterior of the wing apex (rather than somewhat angular terminating at wing apex), and that cell m1 is

considerably broader, (unlikely to exceed twice longer than wide). Further to this, wing patterning, when present in *Acizzia* varies from sparse, inconspicuous stipling generally towards wing apex, to heavy sometimes banded pigmentation. When distinctly banded, the unpigmented pattern generally occurs transversely. In *D. citri*, pigmented areas occur along the anterior and posterior margins of the fore-wing, with the unpigmented band (albeit with some stippling), occurring through the longitudinal axis of wing, terminating with a clear area at wing apex (see Hollis 2004).



Figure 10. Mating adult *D. citri* (left) and honeydew being produced by adult female: both on *M. paniculata* var. *exotica*, Guangdong Entomological Institute (Yang Yueping).

Table 3. Key biological and morphological differences between *D. citri* and *T. erythrae* (after Catling 1970a)

Life cycle stage(s)		<i>Diaphorina citri</i>	<i>Trioza erythrae</i>
Egg			
location		on tips of growing shoots, on and between unfurling leaves	mostly along edges of young leaves
placement on plant tissue		long axis vertical to surface	long axis horizontal to surface
Nymphs			
location		mainly on young stem and petioles	on lamina of underside of leaves
appearance	colour	yellowish brown	variable: yellowish orange, light green, grey
	abdominal spots	no abdominal spots	advanced nymphs with two dark abdominal spots
	sclerites	well-defined sclerites on dorsum	no definite plates or sclerites
	wing pads	massive wing pads	small wing pads
	fringe	large filaments on abdomen only	complete fringe of fine white filaments
	leaf galls	no gall formed, nymphs completely exposed	open gall or pit formed, only dorsal surface of nymph exposed
Adults			
appearance	colour	general colour light brown	overall brown-grey, abdomen lighter ventrally
	wings	head mainly light brown with dark areas (maculate)	head black
			clear and transparent

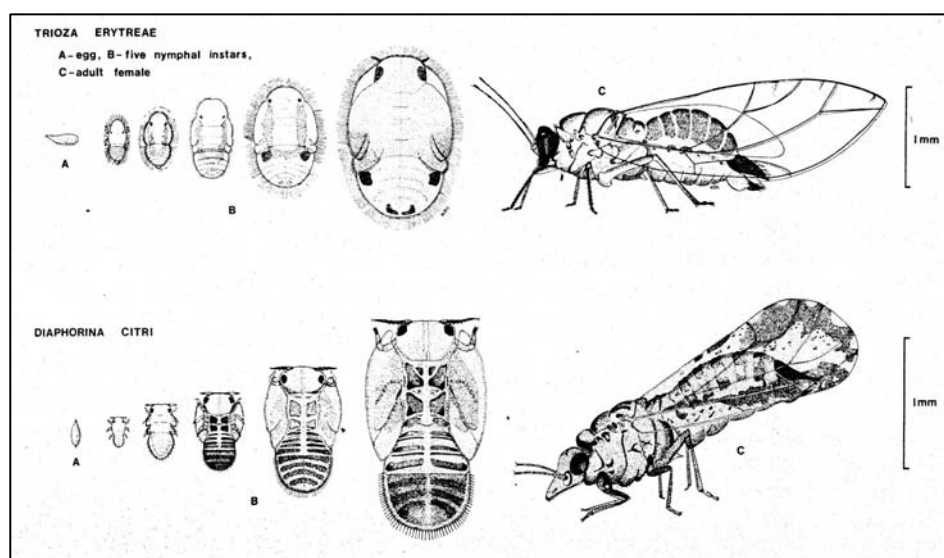


Figure 11. Key biological and morphological differences between *D. citri* and *T. erytreae* (after Catling 1970a).

The draft diagnostic protocols for the detection of the Asian citrus psyllid (*D. citri*) and the African citrus psyllid (*T. erytreae*) (Malipatil & Semeraro 2007) must be peer reviewed and revised.



Figure 12. Teneral adult *D. citri* (light green), nymphs and copious honeydew on *M. paniculata* var. *exotica* sheltered from rain (left) and eggs on young citrus flush (right) (GAC Beattie).

Biology and ecology of *D. citri*

The following is a brief summary of the studies on the biology and ecology of *D. citri*. More detailed information is presented in Appendix X:

- the potential for populations to exist and flourish declines with increasing altitude and latitude (both vary with region) with low altitudes (< 800 m asl depending on region, with a preference for lower altitudes) and high saturation deficits (warm to very hot climates with low relative humidity) preferred to high altitudes and low saturation deficits (warm to hot climates with high relative humidity) (see Aubert 1987c, 1990b, Yang et al. 2006);
- tolerance of low ambient temperatures (e.g., mid winter average daily temperatures between 5.4°C to 6.9°C, with minimums from -5.3°C to -7.5°C (Xia et al. 1988);
- tolerance of temperatures as high as 50°C (Husain & Nath 1927);
- Husain & Nath (1927) reported total life-cycle lengths of 15-47 days, depending on season;

- impacts of climate on adult longevity vary and adults can live for up to 6 to 9 months (Husain & Nath 1927, Xie et al. 1989) in regions with cool to cold winters;
- annual generations depend on regional climates: in the Punjab, Husain & Nath (1927) reported 9, but predicted 11-12 in the presence of suitable flush growth, Atwal et al. (1970) reported 16 in the Punjab, and in China, Yang et al. (2006) reported 6-11 depending on the region where observations were made;
- the host range is mostly within the Aurantioideae with a preference, for *M. paniculata/exotica* and *Citrus* (see Appendix VI);
- host preference is influenced by season, variety, flush morphology, abundance, frequency and duration of flushing;
- psyllid populations can increase rapidly, particularly in spring when the N content of usually abundant flush growth is high and when competition between females for flush growth is low (Atwal et al. 1970, Pande 1972, Koli et al. 1981, Khan et al. 1984, Huang et al. 1990, Hung 2008, Catling 1971);
- *D. citri* reproduces sexually (Husain & Nath 1927);
- the sex ratio is approximately 1:1: Catling (1968, 1970b) reported a sex ratio of 1.23♀:1♂;
- adults mate shortly after eclosion from the fifth and final nymphal instar (Husain & Nath 1927);
- females may produce up to 1900 eggs: Husain & Nath (1927) recorded up to 807 per female, Pande (1971) recorded 180-520 females on citrus twigs, Huang (1990) reported that maximum fecundity was near 1900 eggs, averaging 630–1230, Liu & Tsai (2000) recorded maximum fecundity of 748 eggs at 28°C on orange jasmine, and Tsai & Liu (2000) recorded means of 858, 626, 572 and 612, and maxima of 1378, 830, 818 and 994 respectively on grapefruit, orange jasmine, rough lemon and sour orange seedlings under laboratory conditions;
- females lay their eggs in the growing tips of young host plants, preferring flush growth < 6 mm in length to longer flush lengths: numbers of eggs laid on a flush decline rapidly as the length of flush increases, and when individual leaves attain lengths > 10 mm, and flushes 50 mm (Lin et al. 1973, Chen & Liao 1982, Leong 2006);
- numbers of eggs laid per leaf are greatest on the first leaf, and then progressively lower on the second and subsequent leaves (Xu et al. 1994);
- unfertilised eggs do not hatch;
- the psyllid has five nymphal instars with no diapause;
- oviposition preferences reflect the need for the five nymphal instars of the psyllid to complete their development on immature growth; most eggs are laid within 14 days of new growth commencing (Lin et al. 1973);
- initiation of oogenesis, and subsequent maturation of eggs within ovaries, is closely related to the presence of buds (Dai et al. 1982, Huang 1990, Huang et al. 1999) and breeding activity is largely suspended when citrus trees are dormant (Waterhouse 1998); and
- flight is limited generally to a few metres where hosts are abundant, and possibly limited to 0.5-2 km when searching for a host; dispersal over 90 to 470 km is, or may be, possible in strong winds, such as those associated with cyclones (Aubert & Xia 1990, Sakamaki 2006, Gottwald et al. 2007, Halbert et al. 2008).

Damage caused by *D. citri*

Husain & Nath (1927) were the first to describe damage caused by *D. citri*. In part they said:

‘... *D. citri* neither produces galls nor causes any malformation of the plant tissues. The only sign of injury is defoliation and death of the shoots attacked and the drying up of the branches. On badly infested trees the continual feeding of myriads of insects is, in itself, a very great drain on the food-supply of the plant, but most probably some poison is also injected into tissues of the host and this produces the more serious results. This is evident from the fact

that the fruit of the infested tree is dry and insipid to taste, and branches other than those actually attacked also dry up. Besides, young shoots are killed, old leaves fall off and in course of time an attacked tree is denuded of leaves altogether' 'During the second year of attack, if the pest has been allowed to develop unchecked, all the new shoots are destroyed, and most of the branches are left without leaves and the tree begins to dry up. Very little fruit is borne and that too is of small size, insipid and dry.' They noted that 'The symptoms of attack by the nymphs of the citrus psylla consists in the malformation of leaves which are badly curled, look sickly and fall off prematurely'.

Pruthi & Mani (1945), drawing largely on Husain & Nath (1927) also described damage caused by the psyllid. 'The tree suffers complete defoliation in extreme cases. Apart from defoliation and loss of sap, the nymphs also inject into the plant tissue some toxic substance at the time of sucking the sap. The effect of this toxic fluid is supposed to be the cause of fruits being undersized, poor in juice and being insipid in taste. This also has the effect of causing the branches not directly attacked becoming prematurely dry.' They noted that the psyllid was so very destructive in several parts of India (then including Pakistan) that the citrus industry is often completely ruined and wrote that Husain & Nath (1927) and Pruthi & Batra (1938) believed 'the citrus psylla to be the most destructive of all insect pests of citrus in the Punjab and the North-West Frontier Province'. They cited Husain & Nath (1927) as reporting 'the income of a citrus-grower in the Punjab was once reduced to one-tenth of his usual after a severe attack by the psylla' before noting that 'It is perhaps not so destructive in other countries where it is so far known to occur'. Clausen (1933) and Hoffman (1936) noted that damage caused by the psyllid in Southeast Asia was less severe than damage reported by Husain & Nath (1927) in India before 1930. Clausen (1933) stated that 'The citrus psylla *Diaphorina (Euphalerus) citri* is distributed generally throughout tropical and subtropical Asia, though it does not assume a destructive status in the Philippine Islands, Malaya, or the Dutch East Indies'.

With the benefit of current knowledge, it is clear that the severe symptoms described by Husain & Nath (1927) and Pruthi & Mani (1945) and attributed to *D. citri*, were symptoms now known to be caused by 'Ca. L. asiaticus'. Husain & Nath (1927) were therefore the first authors to describe symptoms of HLB, not Reinking (1919) or Lee (1921), who did not describe symptoms of the disease, as frequently cited in the literature. Damage caused by *D. citri* is much more benign and does not lead to death of trees.

Catling (1968) reported that feeding by *D. citri* causes no malformation of plant tissue, but added, on the basis of a personal communication with CS Celino, that large populations had been observed to cause flower and fruitlet drop in the Batangas Province in the Philippines. In the OEPP/EPPO diagnostic protocol (OEPP/EPPO 2005a), damage is described as 'Heavy infestations can cause blossom and fruitlet drop, and young shoots may be twisted and growth stunted. Sometimes, leaves become badly curled and covered with honeydew and sooty mould. Heavily infested plants may be characterised by the rosette appearance of shoot tips'.

Michaud (2004) observed that in Florida 'Feeding by *D. citri* nymphs often resulted in the abscission of leaves and even whole shoots, and that shoot elongation was abated when death of the apical meristem occurred. Female *D. citri* puncture leaf tissues to embed the egg pedicels during oviposition. This injury sometimes resulted in the blackening and death of damaged tissues, the abscission of apical leaves prior to expansion, and substantial egg mortality that could not be quantified. Plant responses to nymphal feeding ranged from abscission of individual leaves, to death of the apical meristem, and even complete abscission of the terminal.'

Halbert & Manjunath (2004) noted that lateral leaf notching is particularly characteristic of *D. citri* damage in Florida. Such malformations have been also been observed in Brazil (Pat Barkley, pers. obs., 2006). McFarland & Hoy (2001) and Tsai et al. (2002) asserted that distortion of growing shoots and leaves is caused by toxic saliva. They cited Chien & Chu (1996) as the source of this information. However, Chien & Chu (1996) did not mention a salivary toxin. The authors of this document have only rarely observed leaf malformation, particularly notching, caused by the psyllid in Asia, where they have travelled frequently and widely over the past 30 years. These observations are supported by a general lack of any mention of notching in Asian literature. Further research is required to determine the cause of notching observed in Florida and Brazil.

Minor damage, in the form of blemishing of foliage and fruit, is caused by honeydew produced by the psyllid and sooty moulds that grow on this honeydew⁴⁷. Husain & Nath (1927) noted that 'The nymph sucks cell sap and exudes from its anus a thick sugary liquid which is covered over with a waxy secretion of the circumanal gland. This exudation appears as a thick translucent cord. When it has attained a certain size, the insect moves its abdomen from side to side in a characteristic fashion as if rubbing off this matter, and continues to do so till the wax-covered globule of 'honey-dew' drops off. In cases of bad attack the ground under the trees appears white on account of the drops of this sugary secretion. When this matter falls on the leaves it gives them a shining appearance and stickiness. Later on fungus grows on this sugary material and the leaves appear to be covered over with a black sooty deposit'. Halbert & Manjunath (2004) observed curled waxy secretions from nymphs in dry weather. Honeydew melts in hot humid weather (e.g., 36°C-38°C) to form clear droplets (GAC Beattie, pers. obs., 2008).

Trioza erytreae

Distribution of *T. erytreae*

T. erytreae is native to, and occurs widely in, sub-Saharan Africa. It also occurs in Saudi Arabia, Yemen, the Indian Ocean islands of Madagascar, Mauritius, and Réunion, and the Atlantic Ocean islands of Saint Helena, Madeira, Porto Santo, Tenerife and Gomera (Aubert 1987c, OEPP/EPPO 2005b, Bové 2006a).

Hosts of *T. erytreae*

Known hosts of *T. erytreae* are listed in Appendix VII. Its preferred and possibly original rutaceous host is possibly *V. lanceolata* (Moran 1968)⁴⁸. A second species of *Trioza*, *T. litseae* Bordage (syn. *T. eastopi* Orian) has been recorded feeding occasionally on *Citrus* (Aubert & Quilici 1984, Aubert 1987b). However, *T. erytreae* is the only species of *Trioza* that is known to feed and develop on Rutaceae (Hollis 1984).

Description of *T. erytreae*

T. erytreae is one of 389 known species in the genus *Trioza*. The complex of species is difficult to define morphologically but have discrete host plant preferences. Hollis (1984) included 10 species in the *erytreae* group, but there is no single character which will delimit them from other *Trioza* species and the grouping may be artificial. The description of *T. erytreae* below serves to define the group. The species, together with their host plants and distribution are listed in Table 1, and the key in Table 2, of the OEPP/EPPO (2005b) protocol. These can be used to separate species within the group. An adult male is required for identification of most species and instructions on how to prepare specimens are outlined in the OEPP/EPPO (2005b) protocol.

The European and Mediterranean Plant Protection Organization diagnostic standard for *T. erytreae* (OEPP/EPPO 2005b) contains the description below of the adults (including genitalia), the egg, and the fifth instar nymph based on Anneck & Moran (1982) and Hollis (1984).

⁴⁷ See Reynolds (2000) for a review of fungi associated with sooty mould: Reynolds DR. 2000. *Capnodium citri*: The sooty mold fungi comprising the taxon concept. Mycopathologia 148: 141-147.

⁴⁸ Observations reported by Evers & Grisoni (1991), and reports by Temu & Andrew (2008) and Burgess et al. (2002), suggest that two other species of *Vepris*, *V. mildbraediana* G.M. Schulze and *V. morogorensis* var *subalata* (Kokwaro) W. Mziray, may be also be hosts of *T. erytreae*, and possibly 'Ca. L. africanus' in Morogoro, Tanzania.

There are five nymphal instars. The nymphs are dorso-ventrally flattened with a distinct marginal fringe of white, waxy filaments and vary in colour from yellow, olive-green to dark grey. They are largely sedentary and form conspicuous colonies, settling on the underside of young leaves where, after a few days of feeding, they produce distinctive cup-shaped or pit-like, open galls. *T. erytrae* can cause severe leaf distortion, curling, stunting, galling and chlorosis. The leaves may also be dusted with faecal pellets.

Adult. '*T. erytrae* adults are light brown, about 4 mm in length, with large wings and clearly outlined veins. Males are smaller than females and have a blunt tip to the abdomen, the latter ending in a sharp point in females. When feeding, adults take up a distinctive stance, with the abdomen raised at an angle of about 35° to the feeding surface. The detailed morphology is as follows. Integument sparsely covered with short setae; head, in profile, almost at 90° to longitudinal axis of body, from above almost as wide as mesoscutum; occipital margin rounded; vertex pentagonal with anterior margin deeply incised by median suture, rounded down to frons, lateral ocelli on outer sides of raised tubercles, a shallow concavity present on either side of median suture; median ocellus not visible in dorsal view; frons completely covered by genae in anterior view; genal cones well developed, elongate conical with rounded apices; antennal flagellum 2.08–2.81 times longer than head width, head width to length of 1st flagellum in male 1.26–1.70, in female 1.30–1.82; a single rhinarium present subapically on flagellomeres 2, 4, 6 and 7, apical flagellomere with a long pointed seta and a truncate seta apically; clypeus with a pair of setae, ultimate rostral segment with two pairs of setae; thorax, strongly arched; pronotum just visible from above, in profile strongly rounded down behind occiput. Mesopraescutum about as wide as long, its anterior margin strongly arcuate in dorsal view, in profile strongly down curved to pronotum; forewing, hyaline, elongate oval and narrowing to a rounded rectangular apex, 2.79–3.09 times longer than wide, radular areas elongate triangular, remainder of membrane devoid of spinules; veins bearing short setae, *R* branch acutangular, *M* branch distal to *Rs*–*Cu*1a line, *Cu* stem 2.75–4.20 times longer than *Cu*1b, *m*1 cell value 1.10–1.38, *cu*1 cell value 2.56–3.71; forewing 1.59–1.82 times longer than hindwing, costal margin of hindwing with up to two setae proximal to costal break, setae distal to costal break clearly divided into two groups; hind leg, coxa with a well-defined meracanthus and without anterior lobe; tibia with a moderately developed basal spine, with one outer and three (rarely two) inner apical spurs; abdomen, with setae on tergites 2 and 3 in male, and 3 and 4 in female; male proctiger with a laterally expanded basal part and a very short and narrow apical part; paramere as' illustrated 'apical segment of aedeagus simple; female genital segment short, conical, subgenital plate with a ventral bulge, ventral valves of ovipositor weakly serrate apically; measurements (mm) – maximum width of head, male 0.37–0.40, female 0.38–0.46; length of antennal flagellum, male 0.85–1.10, female 0.83–1.10; length of ultimate rostral segment, male 0.09–0.10, female 0.09–0.11; length of forewing, male 2.40–2.96, female 2.61–3.46; length of hind tibia, male 0.50–0.62, female 0.48–0.62.'

Egg. 'The eggs are yellow or orange, cylindrical, with an upturned, sharp, anterior point. Each egg has a short stalk, which is inserted into the plant tissue. They are laid on leaf margins and along the midribs of young, tender, actively growing foliage.'

The nymphs. 'There are five nymphal instars. The nymphs are dorso-ventrally flattened with a distinct marginal fringe of white, waxy filaments and vary in colour from yellow, olive-green to dark grey. They are largely sedentary and form conspicuous colonies, settling on the underside of young leaves where, after a few days of feeding, they produce distinctive cup-shaped or pit-like, open galls. *T. erytrae* can cause severe leaf distortion, curling, stunting, galling and chlorosis. The leaves may also be dusted with faecal pellets.'

Fifth instar nymph. 'Dorsal surface outline oval, about 1.5 times longer than wide. Antenna with 4–5 flagellomeres. Cephaloprothorax separate from rest of thorax, which is entire. Forewing pad about 0.8 mm long, humeral lobe extending forward beyond anterior margin of eye. Caudal plate about 0.65 times as long as wide, anus ventral and distinct from posterior margin of abdomen, anus and pore ring as' illustrated. 'Truncate tubular sectasetae forming a dense, entire marginal fringe, postocular seta absent, sectasetae absent from dorsum.'

Photographs of *T. erytrae* life cycle stages, and damage caused by nymphs, are presented in Fig. 13 (generously provided by Peter Stephen, Citrus Research International, South Africa).



Figure 13. *T. erytrae* fifth instar nymph and egg (left) and an adult female *T. erytrae* (right) (Peter Stephen: Citrus Research International, South Africa).

Biology of *T. erytrae*

The following is a brief summary of the studies on the biology and ecology of *T. erytrae*. More detailed information is given in Appendix X:

- the potential for populations to exist and flourish increases with increasing altitude with populations highest in cool, moist regions up to 1,280 m asl with low saturation deficits, and always low and isolated in the hot, arid lowlands (e.g., 500 m asl) with high saturation deficits;
- frequency and timing of daily saturation deficits above 3.453 kPa have major impacts on populations (Catling 1969b, Green & Catling 1971);
- main influence of extreme weather conditions is the lethal effect on the developmental stages (Catling 1969b);
- the host range in Africa includes citrus, orange jasmine, *Triphasia trifolia* and *Cl. anisata* (all introduced) and native Rutoideae, *V. lanceolata* (the favoured and possibly original host), possibly *Vepris* spp. other than *V. lanceolata*, *Z. capense* and *Toddalia asiatica* (see Appendix VII);
- host preference is influenced by season, variety, flush morphology, abundance, frequency and duration of flushing;
- psyllid populations can increase rapidly, particularly in spring when the N content of usually abundant flush growth is high and when competition between females for flush growth is low (see Catling 1971);
- *T. erytrae* populations multiply rapidly in spring and early summer and less rapidly in autumn and winter (Catling 1971);
- *T. erytrae* reproduces sexually (Catling 1973), and eggs of unmated females are infertile (Catling 1973);
- sex ratios fluctuate but females predominate (Catling 1973);
- mating takes place as soon as the teneral adult hardens, and occurs at all times of the day (Catling 1973);
- adult longevity is 17-50 days depending on season (shorter in summer, longer in winter) (Catling 1973);
- the pre-oviposition is usually 3-5 days in summer (mean temperature 24°C-26°C) and 6-7 days in winter (14°C-16°C) (Catling 1973);
- mated females may lay 217-1305 eggs (Catling 1973: under insectary conditions);

- eggs are laid on the shoot tips of the young flush growth (van der Merwe 1923, Annecke & Cilliers 1963, Moran & Blowers 1967, van den Berg 1990);
- eggs hatch in 6-15 days and nymphal development takes 17-43 days, both strongly correlated with mean temperature (Catling 1973);
- there are five nymphal instars;
- the threshold temperature for nymphal development is probably between 10°C and 12°C (Catling 1973);
- nymphs form open 'pit' galls, mostly on the lower (abaxial) surfaces of immature leaves (van den Berg et al. 1991c);
- adults can disperse, with the aid of prevailing winds, at least 1.5 km (van den Berg & Deacon 1988);
- most flight activity of occurs in two peaks, the first between 10:00 and 11:00 and the second and larger peak shortly before sunset (van den Berg & Deacon 1989);
- in the absence of host plants adults live about 85 and die from desiccation rather than starvation (van den Berg & Deacon 1988);
- adults disperse more frequently as numbers of eggs, nymphs or adults on the citrus increase and when flush growth declines (van den Berg et al. 1991a); and
- movement of adults between citrus orchards and stands of alternative hosts is influenced by season (van den Berg et al. 1991b).

Damage caused by *T. erytrae*

T. erytrae nymphs produce cup-shaped open galls on the under (abaxial) surfaces of leaves of *Citrus* and other Rutaceae on which they feed (see Appendix VII) (Fig. 14). In addition to galling, infestations can cause leaf distortion, curling, stunting and chlorosis (OEPP/EPPO 2005b). Small flush points may be so densely packed with eggs that they may shrivel and fall off (Catling 1972). Chlorosis disappears after nymphs reach maturity (van den Berg 1990). The pellets of excrement (honeydew) voided by this psyllid have the appearance of minute white eggs, and the ground or vegetation under a badly-infested tree may appear as if dusted with white powder (van der Merwe 1941). The severity of these symptoms is related to levels of infestations.



Figure 14. Pit-gall damage caused by *T. erytrae* nymphs (Peter Stephen: Citrus Research International, South Africa).

Other psylloids

Distribution and hosts of other psylloids

In addition to *D. citri* and *T. erytrae*, several other psylloid species are known to feed on Rutaceae, including *Citrus*. They are not known to be vectors of HLB, but limited studies have been undertaken. Species in Southeast Asia include *D. communis* Mathur, *D. murrayi* Kandasamy, and three species of *Psylla* [Psyllidae], *P. murrayi* Mathur, *P. citricola* Yang & Li and *P. citrisuga* Yang & Li. *D. communis* has been recorded on orange jasmine, curry leaf and occasionally from *Citrus* (Mathur 1975), and *D. murrayi* on *M. exotica* L. (Kandasamy 1986). It should be noted that variation within widely distributed species of *Diaphorina* can be considerable between distant populations of each species, and that *D. communis* and other Rutaceae-feeding congeneric species from India may be synonymous (see Burckhardt 1984, 1994, Halbert & Manjunath 2004).

P. murrayi is known to feed and develop naturally on curry leaf, orange, citron and lime (Mathur 1975, Lahiri & Biswas 1980, Osman & Lim 1990). *P. citricola* and *P. citrisuga*, have also been recorded from pomelo and citron in China (Yang & Li 1984). Burckhardt (1994) suggested that *P. citricola* and *P. citrisuga* may be closely related to, or synonyms of, *P. murrayi*. Osman & Lim (1990) observed *P. murrayi* adults on a citrus plant, but considered its presence as occasional or incidental, as they observed no eggs or nymphs. It is odd that none of the species of *Psylla* have been recorded on species of *Clausena*, to which *B. koenigii* is closely related. This may be entirely due to host preferences, but it could also be related to the economic importance of the plants and to mis-identification of hosts. Species in Africa and Indian Ocean islands include *D. auberti* Hollis in the Comores Archipelago (Hollis 1987), and *D. punctulata* Pettey and *D. zebrana* Capener in Swaziland (Catling & Atkinson 1974, Aubert 1987c). *D. auberti* can develop on citrus, with the larvae concentrating on the upper surfaces of young leaves, near the midribs, causing the lateral leaf margins of the leaves to curl upwards and inwards, often forming an enclosed roll (Hollis 1987, citing a personal communication from Bernard Aubert). *D. punctulata* and *D. zebrana* feed on citrus, but are not vectors of '*Ca. L. africanus*' (Catling 1970, Catling & Atkinson 1974).

The psyllid *Mesohomotoma lutheri* (Enderlein) feeds on citrus leaves for short periods, but is extremely rare. Its preferred host is a species of *Hibiscus*. It does not lay eggs on citrus (Aubert & Quilici 1984).

Inoue et al. (2006) recently recorded *Psylla evodiae* Miyatake feeding on *M. paniculata* in Japan, and noted that it occurs on *Tetradium glabrifolium* (Champ. ex Benth.) T. G. Hartley (cited as *Euodia meliifolia* (Hance) Benth.) and feeds on '*Zanthoxylum beechyanum* var. *alatum* (Nakai) Hara'.

Surveys over the past 10 years by CSIRO have failed to detect any psyllids on Aurantioideae in Australia (see Appendix XII). **Any psylloids found on a member of the Aurantioideae should be considered exotic and highly suspect as potential vectors of HLB.**

PATHOGEN ACQUISITION AND TRANSMISSION

The HLB pathogens have been detected in haemolymph and salivary glands of *T. erytrae* and *D. citri* (Chen et al. 1973, Moll & Martin 1973, Xu et al. 1985, 1988a). Jiang (2005) observed that after acquisition from an infected plant, '*Ca. L. asiaticus*' multiplied first in the midgut epithelial cells of *D. citri*, and then penetrated through the basal lamina and entered into the haemocoel, where it multiplied again, before invading other host tissues, including haemocytes, nervous tissue, fat body, trachea, muscle and eventually the salivary gland. Symptoms of serious pathogenesis occurred in

the muscle tissue. The number of mitochondria in pathogen-infected muscle cells was reduced and, the myofilaments and sarcolemma were disrupted. The longevity of infected psyllids was significantly shortened and its fecundity reduced.

Studies reported by Capoor et al. (1974) and Xu et al. (1988a,c) indicated that '*Ca. L. asiaticus*' can only be acquired and transmitted by fourth and fifth instars stages, and adult, *D. citri*. However, Hung et al. (2004), using PCR, detected '*Ca. L. asiaticus*' in second, third, fourth and fifth instar nymphs and adult *D. citri*. van den Berg et al. (1991-1992) reported that second to fifth instar *T. erythrae* nymphs can acquire '*Ca. L. africanus*', and that a small proportion of fourth and fifth instar nymphs could transmit the pathogen. In contrast, studies by McClean & Oberholzer (1965a), Catling (1969c), Moll & Martin (1973) and Catling & Atkinson (1974) indicated that the adult *T. erythrae* can transmit the '*Ca. L. africanus*' but that nymphs failed to do this. In other studies (McClean & Oberholzer 1965a, Catling 1969c, Moll & Martin 1973, Catling & Atkinson 1974) no evidence was found that nymphs can acquire '*Ca. L. africanus*'.

McClean (1974) reported observations that indicated that the number of adult *T. erythrae* carrying the African HLB pathogen was relatively small in relation to the total adult population found on trees in South Africa, in a region where the incidence of the disease was high. He reported evidence of seasonal fluctuations in the number of carriers: more occurring among adults emerging from the summer flushes on citrus trees, and few, if any, among those emerging during winter and early spring. However, he noted that the efficiency of the vector was not seriously impaired by the small number of carriers; it was offset by the large numbers of adults that emerged during favourable conditions, thus insuring spread of the disease to many healthy trees, and to healthy sectors of partially diseased trees. McClean (1974) also observed that attempts to infect psylla experimentally by feeding them on diseased sources succeeded only very occasionally. In contrast, adults collected from diseased trees in the field were always more effective in transmitting the disease. He found no evidence of that the causal organism of African HLB is passed through eggs laid by infective adults. However, van den Berg et al. (1991-1992) reported transovarial transmission of '*Ca. L. africanus*' by *T. erythrae*.

Transovarial transmission of '*Ca. L. asiaticus*' does not occur in *D. citri* (Capoor et al. 1974, Xu et al. 1988a, Hocquellet et al. 1999, Hung et al. 2004). Hung et al. (2004) based their conclusions on PCR tests of eggs and nymphs (not held on infected plants) from infected females.

Experiments have shown that both psyllids can transmit '*Ca. L. asiaticus*' and '*Ca. L. africanus*' (Massonie et al. 1976, Lallemand et al. 1986), and *D. citri* transmits '*Ca. L. asiaticus*' and '*Ca. L. americanus*' in Brazil (Yamamoto et al. 2006).

Diaphorina citri

In laboratory studies in India, Capoor et al. (1974) conducted several transmission studies with '*Ca. L. asiaticus*' based on healthy and diseased Mosambi sweet orange seedlings. They found that:

- adults maintained on diseased seedlings could infect healthy seedlings within 24 h;
- when single psyllids were used for transmissions, 68% of plants (n = 60) became infected;
- when ≥ 5 adults were used per plant, all 60 initially pathogen free plants used became infected;
- adults tested in groups of 5 were able to infect 90% of plants (n = 50) after feeding on infected plants for 15 min, and 100% of plants after feeding on diseased plants for 30 min;
- there were low levels of transmission when infected adults were permitted to feed on pathogen free trees for 15 min, compared to 100% transmission when they were allowed to feed for 1 h;

- initially pathogen-free adult psyllids were able to transmit the pathogen within 8 (10%) to 12 (100%) days of feeding on diseased plants;
- once infected, psyllids remained infected for their lifetime;
- fourth and fifth instar nymphs could acquire the pathogen and transmit it at high rates (96.5%, n = 200 plants); and
- there was no evidence for transovarial transmission

Xu et al. (1988a) reported that HLB was successfully transmitted from diseased citrus plants to healthy mandarin seedlings by fourth and fifth instar nymphs of *D. citri*, but not by first to third instar nymphs. A single adult could transmit the pathogen very efficiently. The latent period for adults was as short as 1-2 d, and as long as 25 d, after acquisition feeding. Infected adults retained infectivity throughout their lives. Adults that eclosed from infected nymphs transmitted the pathogen to healthy seedlings without need for an acquisition feeding. The authors (Xu et al. 1988a) reported that transmission of HLB by the psyllid was highly efficient (one adult per plant gave 80% transmission), but noted that transmission in earlier studies, including those reported by Huang et al. (1984) and Xu et al. (1985), ranged from 1.3% to 12.2%. Xu et al. (1988a) attributed their high transmission rates to differences in procedures, noting that: (a) the young diseased mandarin seedlings used as source plants were inoculated by psylla and were examined to be sure they contained the pathogen; (b) mandarin seedlings with 3-4 leaves, possibly the most susceptible stage, were used for inoculation; (c) psyllids were fed on a diseased source plants not collected directly from the field; and (d) test plants were held under controlled shade levels that may have favoured symptom development. Jiang (2005) observed that *D. citri* adults were able to transmit 'Ca. L. asiaticus' to host plants 7 days after acquisition from infected plants. Hung (2006) found that transmission of 'Ca. L. asiaticus' by adult *D. citri* to be < 5%, and commented that psyllids primarily acquired the pathogen in the nymphal stage (Hung 2008).

Huang et al. (1990) reported that peak transmission of HLB occurred from mid spring to early summer in Taiwan. Chavan (2004) reported that transmission to pathogen-free sweet orange seedlings by nymphs collected from HLB-infected trees in Maharashtra in February (early spring) was 67% compared to 33% in May; transmission by adults was 45-50% in February-March, and concluded that transmission peaked from early to mid spring. Adult transmission rates of 43% and 25% were recorded in January-February and March respectively.

Manjunath et al. (2008) recorded seasonal levels of 'Ca. L. asiaticus' infection in *D. citri* populations in Florida. The highest levels of infections were found in September/October (autumn), probably coinciding with feeding on fall flushes. The results suggested that, even though psyllid populations may reach a peak in April (spring flush), higher incidence of 'Ca. L. asiaticus' infection may occur in autumn when populations are much lower. The populations rose rapidly from low levels in January-February (winter) to peak in April (spring), before declining to low levels again by August (late summer). This suggests that seasonal titres of bacteria fluctuate in susceptible host plants, and consequently in the vectors, falling in summer due to the impact of high leaf temperatures, when ambient temperatures and solar radiation are high, saturation deficits low, and relative humidities high.

Trioza erytreae

McLean & Oberholzer (1965a) reported the first positive transmission of HLB by *T. erytreae*. van den Berg et al. (1991-1992) noted that the duration of the acquisition period plus the period before the insect is able to transmit the disease has previously been given as 21 d (Moll & Martin 1973), but observations reported by van Vuuren et al. (1986) indicated that the interval could be as short as only 2 d. Subsequently, van Vuuren & van der Merwe (1992) allowed healthy *T. erytreae*

to feed on ‘*Ca. L. africanus*’-infected citrus seedlings for 1, 2, 4, 8 and 24 h. After feeding, adults were transferred to healthy citrus plants at 1 to 7 d intervals to establish the latent period for the insects to become infective. They observed that adults were able to transmit the pathogen at a high rate within 7 d after a 1 d acquisition feeding on the infected plants, and that they could acquire the pathogen within 1 h of feeding. A latent period of 3-4 d was required before transmission occurred after acquisition feeding for 1, 2 and 4 h. No latent period was present after acquisition feeding for 8 and 24 h. Transmission was low (4 to 12 %) when adults, irrespective of the time they feed on infected seedlings to acquire the pathogen, were allowed up to 4 days to transmit the pathogen to healthy plants, but increased to 32% when they were allowed to transmit the pathogen over 7 d. Transmission also increased when the length of the acquisition feeding times was increased (11 % for 1 h to 23 % for 24 h).

HUANGLONGBING

Known hosts of HLB are listed in Appendix V, the tables within which are based on Halbert & Manjunath (2004), and other sources as cited, that have been modified to account for recent changes in the classification of *Citrus* and, more broadly, the Aurantioideae and the Rutaceae (Bayer et al. 2009).

Distribution of the disease

HLB is known to occur:

- In South and Southeast Asia (from the Indian subcontinent to the Philippines, Indonesia, East Timor and Japan), New Guinea (Papua and Papua New Guinea) (Tirtawidjaja et al. 1965, Capoor et al. 1967, Martinez & Wallace 1967, Teaching & Research Group of Phytopathology of Guangdong Agricultural and Forest College 1977, Garnier & Bové 1996, 2000b, Weinert et al. 2004);
- In the Arabian Peninsula, in Saudi Arabia where ‘*Ca. L. asiaticus*’ is transmitted by *D. citri*, in Yemen where a ‘heat-sensitive form’ is transmitted by *T. erytrae*, and north of the Saudi Arabia/Yemen border, where both vectors are associated with both ‘*Ca. L. asiaticus*’ and ‘*Ca. L. africanus*’ (Bové & Garnier 1984);
- In Africa, caused by ‘*Ca. L. africanus*’ and transmitted by *T. erytrae* (McClellan & Oberholzer 1965a, McClellan 1974, Garnier & Bové 1996);
- In Mauritius and Réunion caused by ‘*Ca. L. asiaticus*’ and ‘*Ca. L. africanus*’ and most probably transmitted by both vectors (Massonnet et al. 1976, Lallemand et al. 1986, Aubert 1987b, Garnier et al. 1996);
- In the United States of America (Florida and Louisiana⁴⁹) and Cuba, caused by ‘*Ca. L. asiaticus*’ and transmitted by *D. citri* (Halbert 2005, Gottwald et al. 2006, Martínez et al. 2008⁵⁰); and
- In Brazil caused by ‘*Ca. L. asiaticus*’ and ‘*Ca. L. americanus*’⁵¹ and transmitted by *D. citri* (Teixeira et al. 2005a, b).

A sub-species, ‘*Ca. L. africanus* subsp. *capensis*’, occurs in Cape chestnut (*Calodendrum capense* Thunb. [Rutaceae: Rutoideae]), an ornamental tree in southern Africa (Garnier et al. 2000).

⁴⁹ see: Animal and Plant Health Inspection Service Plant, DA-2008-24, 13 June 2008 -

http://www.aphis.usda.gov/plant_health/plant_pest_info/citrus_greening/downloads/pdf_files/spro-da-2008-24.pdf

⁵⁰ The distribution of HLB in the Americas is likely expand relatively quickly given the rapid spread of *D. citri* in the region, and is likely to be wider than currently reported. **The disease may be present in regions, including Australia, where the vectors do not occur, but in the absence of its vectors it is not able to survive indefinitely or spread, unless by propagation.**

⁵¹ Lou et al. (2008) reported detection of ‘*Ca. L. americanus*’ in citrus, in a single leaf sample, collected in Hunan, China.

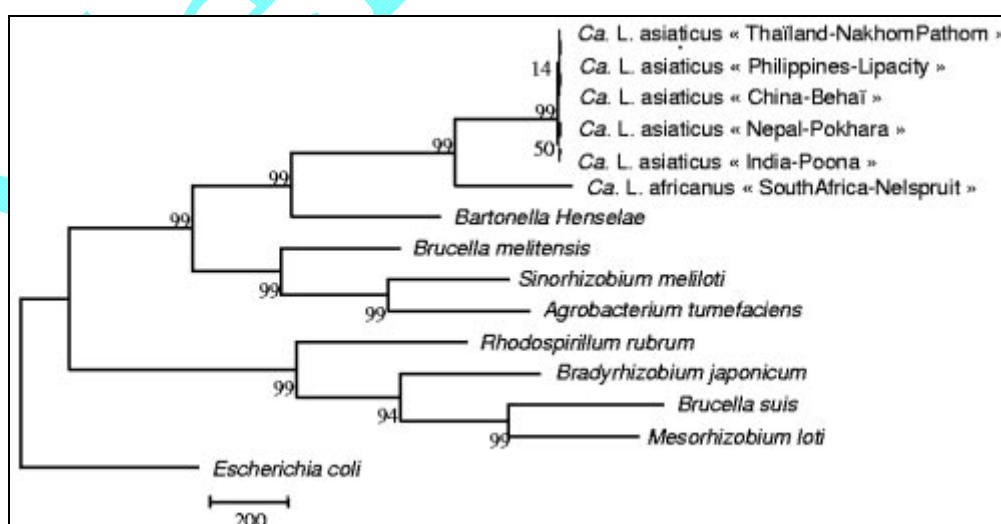
See Garnier & Bové (2000a) and Bové (2006a) for a detailed summary of disease distribution.

The disease has not been recorded in Australia (Bellis et al. 2005).

Huanglongbing pathogens

HLB pathogens are phloem limited, fastidious Gram-negative bacteria (Garnier et al. 1984) that were discovered by electron microscopy in 1970 (Lafèche & Bové 1970a). They have, unless recent reports (Davis et al. 2008, Schuenzel et al. 2008b) are correct, resisted *in vitro* cultivation, hence the designation of '*Candidatus*' as an interim taxonomic status (Murray & Stachenbrandt 1995). The HLB bacterium has been shown by 16S rDNA sequence comparisons to be the first member of a new sub-group in the α -Proteobacteria (Jagouiex et al. 1994, Garnier et al. 2000)⁵². The liberibacters from Africa and Asia can be distinguished on the basis of temperature sensitivity (Bové et al. 1974), DNA hybridisations and genetic properties (Villechanoux et al. 1992, 1993) and serology (Garnier et al. 1991, Gao et al. 1993) and so have been designated as different forms: '*Ca. L. asiaticus*' Garnier and '*Ca. L. africanus*' Garnier (Jagouiex et al. 1994, Garnier et al. 2000). The liberibacter from São Paulo State, Brazil (occurring in addition to '*Ca. L. asiaticus*') has been designated '*Ca. L. americanus*' (Teixeira et al. 2005a, b, c) on the basis of its sequence divergence from the other two forms. A sub-form, '*Ca. L. africanus* subsp. *capensis*' was detected in Cape chestnut (Garnier et al. 2000).

As well as the different species of HLB pathogen, variation within a 'species' has been shown using serological and molecular based techniques. The use of monoclonal antibodies (MA) for the detection of HLB-bacteria has shown that each MA is very specific for the strain used for immunisation and therefore they cannot be used for generalised diagnosis of HLB (Garnier et al. 1991). Outer membrane protein (*omp*)-based PCR-RFLP analysis was used to successfully detect and differentiate isolates within '*Ca. L. asiaticus*', again demonstrating that variants of the pathogen exist (Bastianel et al. 2005). The genetic diversity of '*Ca. L. asiaticus*' isolates, as revealed by PCR-RFLP analysis is in good agreement with serological studies showing the occurrence of seven distinct serotypes (Gao et al. 1993). Recently, a phylogenetic tree was constructed from the *omp* gene sequences of the African and Asiatic liberibacters, and confirmed the phylogeny based on 16S rDNA sequences (Bastianel et al. 2005) (Fig. 15).



⁵² Hansen et al. (2008) recently reported a new form of liberibacter in tomato and potato and erroneously referred to it as a 'new huanglongbing (HLB) *Candidatus* species' apparently not realising that huanglongbing describes symptoms of a specific disease (yellow shoot disease) of *Citrus* and other Rutaceae. The most similar 16S rRNA sequence to this new *Candidatus* Liberibacter species is sequence DQ471901 '*Candidatus* Liberibacter asiaticus' 17 from Brazil, which possesses 97% sequence similarity and a total Blast score of 1965.

Figure 15. Maximum-parsimony phylogenetic tree generated from alignment of *omp* sequences from ‘*Ca. Liberibacter*’ and other α -Proteobacteria. Bootstrap values are shown at the nodes. *E. coli* was added as an outgroup (from Bastianel et al. 2005).

While the 16S rRNA gene sequences of ‘*Ca. L. asiaticus*’ and ‘*Ca. L. africanus*’ had 98.4% similarity, the 16S rRNA gene sequence of the SPS-HLB liberibacter (‘*Ca. L. americanus*’) had only 96% similarity with the 16S rRNA gene sequences of ‘*Ca. L. asiaticus*’ or ‘*Ca. L. africanus*’. This lower similarity was reflected in the phylogenetic tree, where the SPS-HLB liberibacter did not cluster within the ‘*Ca. L. asiaticus*’/‘*Ca. L. africanus*’ group, but as a separate branch (Teixeira et al. 2005c) (Fig. 16). A similar phylogenetic tree was obtained by Teixeira et al. (2008) based on deduced amino acid sequences of *rplJ*.

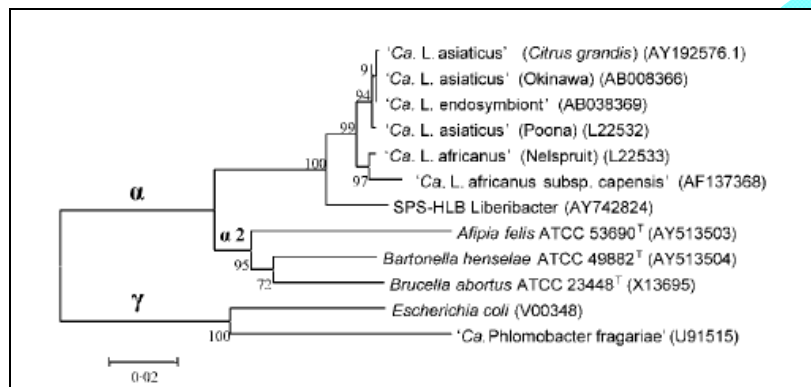


Figure 16. Phylogenetic tree constructed from 16S rRNA sequences obtained from GenBank (accession numbers in parentheses) using MEGA version 2.1. (Teixeira et al. 2005c).

Liefting et al. (2008) found that the tomato/pepper liberibacter ‘*Candidatus L. solanacearum*’ does not appear in the ‘*Ca. L. americanus*’ and ‘*Ca. L. asiaticus*’/‘*Ca. L. africanus*’ clades, but terminates on its own branch (see Fig. 17). The percent nucleotide identity showed that the tomato/pepper liberibacter is marginally more closely related to ‘*Ca. L. asiaticus*’ and ‘*Ca. L. africanus*’ than to ‘*Ca. L. americanus*’. The sequence of ‘*Ca. L. solanacearum*’ shared 96% identity with the 16S rRNA gene of both ‘*Ca. L. asiaticus*’ and ‘*Ca. L. africanus*’ and 95% identity with ‘*Ca. L. americanus*’.

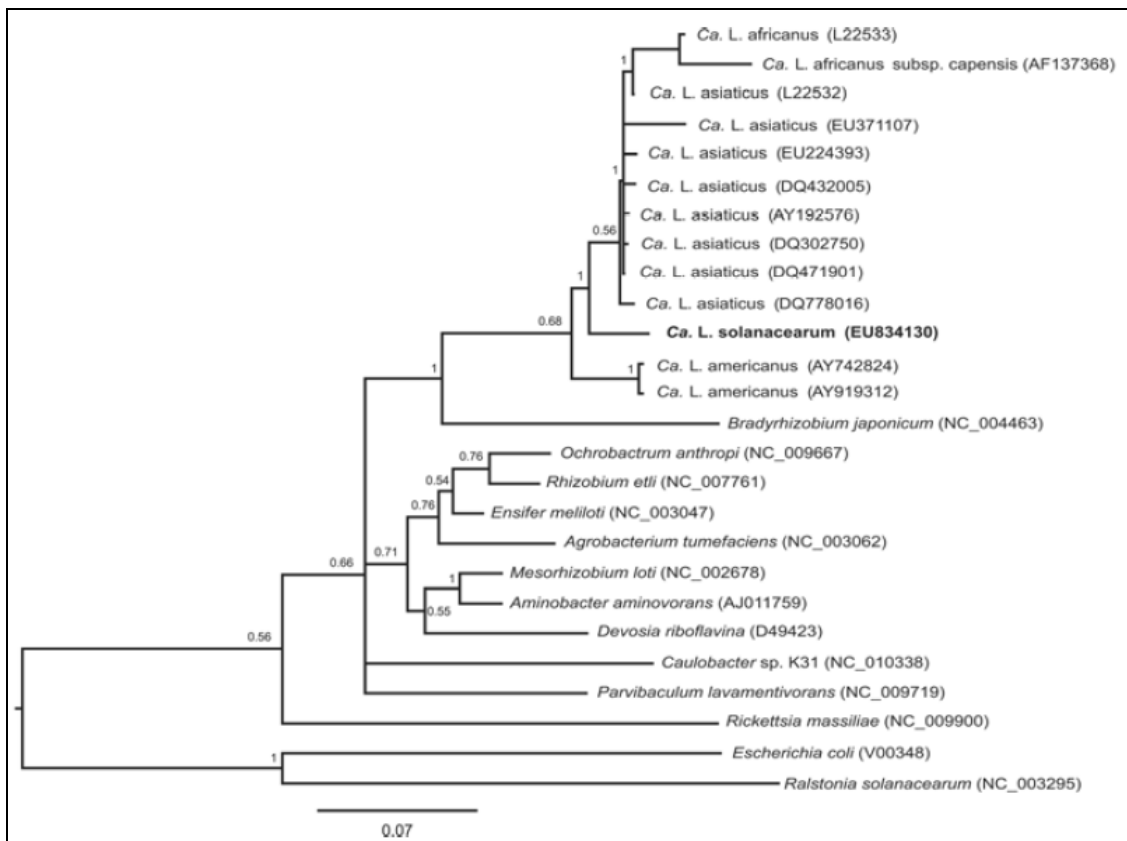


Fig. 17. A 50% majority rule consensus Bayesian inference phylogenetic tree based on 16S rRNA sequences showing the relationships of the four ‘*Candidatus Liberibacter*’ species and representatives of the alpha subdivision of the *Proteobacteria*. *Escherichia coli* was used as an outgroup. GenBank accession numbers are given in parentheses. Posterior probabilities are indicated above nodes. Scale bar shows inferred number of changes per site. From Liefting et al. (2009).

The *omp* gene sequences were also used to study the diversity of several strains of ‘*Ca. L. asiaticus*’. Each strain could be characterised by a specific PCR-RFLP profile (Bové 2006a). ‘*Ca. L. asiaticus*’, even within a geographic region includes several different variants which can be distinguished by PCR-RFLP, based on the *omp* gene sequence. Subandiyah et al. (2006) proposed that there are two strains ‘*Ca. L. asiaticus*’ in Indonesia, based on the sequence of phage DNA-polymerase gene and natural infection was found to be either by a single strain or both strains. Teixeira et al. (2005c) stated that ‘Within the genus ‘*Candidatus Liberibacter*’ and for a given species, the 16S/23S intergenic region does not vary greatly. The intergenic regions of three strains of ‘*Ca. L. asiaticus*’, from India, the People’s Republic of China and Japan, were found to have identical or almost identical sequences. In contrast, the intergenic regions of the SPS-HLB liberibacter, ‘*Ca. L. asiaticus*’ and ‘*Ca. L. africanus*’ had quite different sequences, with similarity between 66.0 and 79.5%’.

Doddapaneni et al. (2008a) showed that ‘there is very little sequence variation among the different *Ca. Liberibacter* species suggesting strong host and/or environmental selection and a genetically stable lineage of the pathogen. The 16S sequences were more conserved among the Las strains while; a slightly higher degree of sequence variation was noted for the Laf strains. Alignments for a ~1.5 Kb region of the *rpoB* of Las strains and Laf strains revealed that strain from China differed by two SNPs from the Japan, Florida and Brazil strains, which were identical at this locus. These two SNPs were possibly introduced later in the Chinese strain after their separation from the other Las strains.’⁵³

Zhou et al. (2008d) observed different types of symptoms on citrus in the field, and on HLB-affected periwinkles when the disease was transmitted from ‘*Ca. L. asiaticus*’-infected citrus to

⁵³ Laf – ‘*Ca. L. africanus*’; Las – ‘*Ca. L. asiaticus*’; Lam – ‘*Ca. L. africanus*’.

periwinkle via dodder. More importantly, these different types of symptoms could be maintained by graft transmission, indicating they are not caused by genetic variation of host plants, but possibly by genetic variation of the pathogens. Mixed populations of individual forms of ‘*Ca. L. asiaticus*’/‘*Ca. L. americanus*’ bacteria occurred within a single HLB-affected plant.

Symptomatology of HLB in *Citrus*

Key HLB symptoms (Lin 1956, Schneider 1968a, McClean & Schwarz 1970, Tirtawidjaja 1980, Zhao 1981, da Graça 1991, Gottwald et al. 2007, Bové 2006a) in infected citrus plants are:

- leaves with asymmetric, sometimes dull, blotchy-mottling that crosses leaf veins;
- mottled or complete yellowing of leaves and growing shoots (yellow shoots standing out from an otherwise normally green canopy);
- small upright, thickened, chlorotic leaves (sometimes resembling mineral deficiencies, particularly Zn);
- flushing of severely greened trees out of phase with healthy trees;
- dieback of branches;
- vein-corking associated with ultrastructural changes to phloem (but note that CTV and boron deficiency can also cause vein-corking; see **Mixed infections of HLB and CTV**, and **Ultrastructural Changes**);
- unseasonal and heavy flowering on diseased branches;
- small, lopsided, bitter tasting fruit with small dark and aborted seeds;
- unevenly coloured maturing fruit (particularly sweet oranges and mandarins in temperate and subtropical regions) on which the styler (outer) end remains green, as the peduncle (calyx) end turns orange;
- excessive fruit drop; and
- ‘silver imprint’ when finger pressure is applied to the fruit.

Photographs of some of these key symptoms are presented in Figs. 18 to 26.

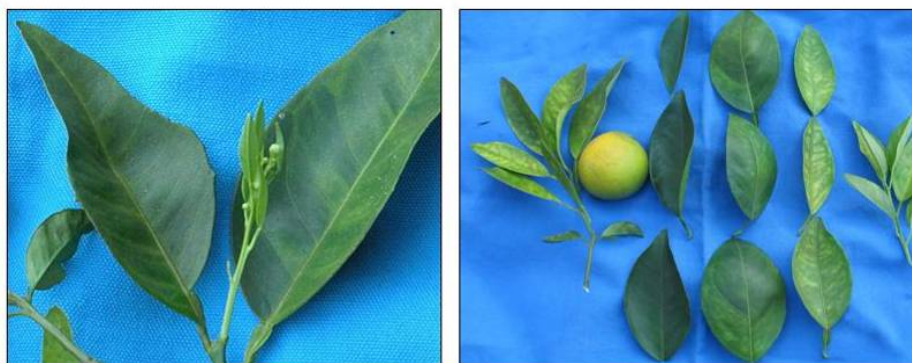


Figure 18. Leaves with asymmetric, sometimes dull, blotchy-mottling that crosses leaf veins (Pat Barkley: Brazil 2006).



Figure 19. Yellow shoots standing out from canopy
(left, GAC Beattie: Florida 2007; right, Pat Barkley: Brazil 2006).



Figure 20. Mottled leaves
left, pomelo leaves in Hong Kong (Pat Barkley, 1969)
right, sweet orange leaves in Florida (GAC Beattie, 2007) with small upright, thickened, chlorotic leaves, some with green islands, and some resembling mineral deficiencies, particularly Zn.



Figure 21. Yellow veins
left, sweet orange leaves in Brazil (Pat Barkley, 2006)
right, sweet orange leaves in Florida (GAC Beattie, 2007)



Figure 22. Unseasonal flowering on diseased sweet orange branches in Brazil (Pat Barkley 2006).



Figure 23. Dieback of branches and small, upright leaves with Zn deficiency-like patterns (GAC Beattie: Java, Indonesia, 2003).



Figure 24. Vein-corking of pomelo leaves associated with ultrastructural changes to phloem (GAC Beattie: Việt Nam 2007).



Figure 25. Small, lopsided, bitter tasting fruit (left & right) with small dark and aborted seeds (right) (Pat Barkley: Brazil 2006)



Figure 26. Silver imprint' when thumb pressure is applied to immature fruit from diseased trees (left) and unevenly sized fruit, one with an abnormal red-brown button (right) (Pat Barkley: Brazil 2006).

As disease severity increases, yield is reduced, mainly by the early drop of fruit from affected branches. The yield reduction can reach 30 to 100%, depending on proportion of affected canopy (Aubert et al. 1984, Bassanezi et al. 2006a) and makes the orchard economically unviable 7 to 10 years after planting (Gottwald et al. 1991, Roistacher 1996). Affected fruit are smaller, lighter, very acid, with reduced Brix/acid ratios, percentage of juice and soluble solids and can affect the juice quality.

McClellan & Schwarz (1970) noted two types of leaf symptoms for African HLB. 'Some leaves turn yellow along their main and secondary veins. The "yellow-vein" appearance later changes to a blotchy-mottle as the discoloration spreads away from the veins. The leaves showing this symptom are mostly the larger ones on the lower parts of branches, those on short branches back in the tree, and those on the more vigorous shoots that develop during the late summer flush. The yellow discoloration usually develops at some stage after the leaves mature.'

Leaves on weak terminal twigs are small, upright and show a variety of chlorotic patterns, superficially suggestive of zinc and iron deficiencies. The small leaves are pale at first and develop secondary chlorotic patterns as they mature. They sometimes turn yellow but more often remain pale and turn green along the main and lateral veins. Sometimes green spots and green blotches develop. The intensity of these symptoms varies a lot. They may be well defined, or only slight with the small terminal leaves mostly green and only a few of them showing a slight interveinal chlorosis.'

Photographs published by McClellan & Schwarz (1970) of African HLB symptoms are presented in Figs 27 & 28.

Schneider (1968a) distinguished symptoms as primary and secondary. The primary symptoms appear on leaves after they mature normally, whereas the secondary symptoms appear on leafy shoots as they grow from branches with primary symptoms.

Primary leaf symptoms 'do not result from immediate anatomical changes caused by the virus in the plant, but rather from secondary anatomical changes. The latter are responsible for a yellow, angular blotching, leatheriness, vein clearing, and vein yellowing. The angular blotching has been considered specific for the disease and consists of blotches of yellow on dark greenish-gray leaves. The margins of the blotches are sometimes straight when they follow veins and angular when they follow intersecting veins. Blotching occurs only on mature leaves, the symptom being found by looking back into the tree at older leaves' (Schneider 1968a).

Secondary leaf symptoms 'of greening are further removed from initial effects of virus than are the symptoms designated as primary, and they occur on shoots that grow from virus-weakened branches exhibiting primary symptoms. Secondary symptoms appear during morphogenesis of leaves and consist of several chlorotic leaf patterns that are similar to evidences of mineral deficiencies in citrus, namely Zn, Fe, Mn, Ca, S, and B. Symptoms resembling those of zinc deficiency are the most common, e.g., the leaf blade along the mid and main lateral veins is green, but the inter-veinal areas are yellow; in extreme cases, leaves remain small, erect, and yellow with green spots, as with acute zinc deficiency. Chlorotic leaves usually abscise, and the twigs that bear them die.

On the same tree, some branches may be free from symptoms, others may show primary symptoms, and still others, secondary symptoms. The virus moves slowly or not at all from one side of a mature tree to another, and systemic infection seems to depend on multiple insect inoculations' (Schneider 1968a)⁵⁴.

As noted above by McClean & Schwarz (1970), symptomatology varies with season. Symptom development may be delayed for several months, or as long as 2 to 3 years after infection (Lin 1956, Zhao 1981, Capoor et al. 1974, Hung et al. 2001, Gottwald et al. 2007). Zhao (1981) noted that while some symptoms vary between different citrus species and varieties (see Table 1), it is not significant in a diagnostic sense.

'*Ca. L. africanus*' is not as aggressive as '*Ca. L. asiaticus*' and symptoms of African greening, caused by '*Ca. L. africanus*', are less severe than Asiatic HLB, caused by '*Ca. L. asiaticus*', and the two forms can be distinguished on the basis of temperature tolerance (le Roux et al. 2006a). Leaf symptoms of African HLB are more pronounced in the cool areas, than in the low-lying hot areas and are more pronounced in winter (Schwarz 1968a). '*Ca. L. africanus*' is inactivated by lower temperature×time impacts (Schwarz & Green 1972). Severe symptoms caused by '*Ca. L. africanus*' are obtained under cool glasshouse conditions (22°C for 8 h nights and 24°C for 16 h days), whereas no symptoms occur at temperatures ranging from 27°C to 30°C. The higher temperature for an extended period appears to inactivate the African form (Schwarz & Green 1972, Labuschagne & Kotze 1988). '*Ca. L. asiaticus*' is inactivated at higher temperatures (Zhao 1981, Lin et al. 1965, Su & Chang 1974, Huang 1978, Lo 1983, Cheema et al. 1982, Su & Chu 1984, Song et al. 1999) and such inactivation appears to influence the severity of the disease in parts of Asia, where rates of decline of trees appear to be slower, for example, in Pakistan, than in cooler Southeast Asia.

Symptoms produced by '*Ca. L. americanus*' and '*Ca. L. asiaticus*' also differ in their sensitivities to high temperatures (Lopes et al. 2008). When infected citrus trees were maintained for 60 days at 27°C to 32°C, or for 90 days at 24°C to 35°C, complete symptom remission in the new vegetative flushes was observed in '*Ca. L. americanus*'-, but not in '*Ca. L. asiaticus*'-infected trees. Contrary to the '*Ca. L. asiaticus*'-infected trees, '*Ca. L. americanus*' was not detected in any previously infected tree. '*Ca. L. asiaticus*' was however affected by the 24°C to 38°C daily cycle, conditions totally unfavourable to '*Ca. L. americanus*', and these were PCR-negative after two years (Lopes 2008a,b).

⁵⁴ The results of a girdling experiment reported by Martinez (1973) suggest that spread of infection in trees may also be related to rates of movement of bacteria in phloem in relation to rates of formation and natural death of phloem bands. Each flush cycle leads to a new band of phloem being formed by cambium in limbs and trunks of trees, and incorporation of the naturally dying outer band of phloem into the outer bark of trees. Pathogens in such phloem would also die. It is highly likely that the structure of phloem bands, with zones of functioning and non-functioning sieve elements, would limit movement of HLB pathogens from one band to another. Thus, movement of the pathogens in most instances would be vertical and spread of bacteria over short distances within canopies of small trees, with abundant young flush, would be more rapid than over greater distances in mature trees with proportionally fewer young flushes.

Variable transmissibility of isolates of '*Ca. L. africanus*' from different areas may be due to titres of the organism within the tissue that could be affected by climate (van Vuuren 1993). A higher transmissibility rate indicates a higher titre of the organism, which will favour insect transmission (van Vuuren & van der Merwe 1992).

'*Ca. L. asiaticus*' is more readily graft transmissible and reaches higher titres in citrus than '*Ca. L. americanus*' (Lopes 2008a).



Figure 27. Photographs (Figs 12 to 24) of African HLB symptoms (from McClean & Schwarz 1970)

GREENING OR BLOTCHY-MOTTLE DISEASE OF CITRUS



FIG. 25



FIG. 26



FIG. 27



FIG. 28



FIG. 29



FIG. 30



FIG. 32



FIG. 35



FIG. 31



FIG. 33



FIG. 37



FIG. 36



FIG. 34



FIG. 38

Figure 28. Photographs (Figs 25 to 38) of African HLB symptoms (from McClean & Schwarz 1970)

Symptomatology of HLB in *Murraya* spp.

Lopes et al. (2006a) reported that *M. paniculata*, as street trees in Brazil, show yellow leaves and shoot dieback, principally due to 'Ca. L. americanus', and occasionally by 'Ca. L. asiaticus'. Symptoms were present in one or more sectors of the tree canopy. Contrary to what happens in citrus, mottled leaves or deformed fruits were not found in *Murraya*, which makes field diagnosis more difficult. *Murraya* test plants showed mineral deficiency-like patterns.



Figure 29. *M. paniculata* var. *exotica* with HLB by graft transmission in Brazil (Pat Barkley).



Figure 30. *M. paniculata* var. *exotica* with HLB following transmission by *D. citri* from a nearby HLB-infected citrus tree at South China Agricultural University in studies conducted by Deng Xiaoling: the plants were initially PCR positive for HLB when symptoms developed, but PCR negative 6 months later (GAC Beattie, 13 April 2007).

Mixed infections of HLB and CTV

Dual CTV and HLB infection has been reported to produce more severe symptoms than individual infection by either pathogen (Martinez & Wallace 1967, Martinez 1972, Bhagabati & Nariani 1980, Prommintara 1990).

Davis et al. (2005) investigated ‘*Ca. L. asiaticus*’ and citrus tristeza virus (CTV) interaction in terms of effect on symptoms and found that in trees that were positive for both pathogens, CTV infection had little effect on HLB leaf symptoms, with chlorotic blotch and corky veins being prominent⁵⁵.

Chen et al. (1972) found that likubin-diseased trees are frequently infected with both ‘*Ca. L. asiaticus*’ and CTV. Within the phloem, the pathogens were encountered both in widely separated and in adjacent cells. Cells rarely contained both pathogens. They also commented that the severity of external symptoms often is not directly related to the amount or appearance of internal symptoms.

In South Africa, some isolates of CTV may protect trees from the fruit symptoms of HLB (van Vuuren et al. 2000).

Confusion with Other Diseases and Nutrient Disorders

The distinction of HLB symptoms from nutrient deficiency symptoms (Fig. 31) can be difficult (Catling 1970). Halbert & Manjunath (2004) stated that leaf mottling resulting from HLB infection differs from symptoms of nutrient deficiencies, as it usually crosses leaf veins, rather than occurring between or along the veins.

Tirtawidjaja et al. (1965), Koen & Langenegger (1978) and Aubert (1987b) described mineral imbalances in HLB-affected citrus in a cursory manner. In HLB infected trees, Tirtawidjaja et al. (1965) reported higher N and P in young leaves, higher Ca in older leaves and lower Mn, Fe and Zn. Manicom & van Vuuren (1990) reported markedly reduced calcium, iron, magnesium, manganese and zinc levels and elevated potassium, sodium and chloride values in HLB-infected trees in South Africa. Matsumoto et al. (1961) recorded elevated amylase activity and glucose and fructose levels and a reduction in the organic citric, malic and succinic acids in HLB-infected leaves. Pustika et al. (2008) suggested that HLB infection restricts either nutrient uptake or transport and, therefore, that foliar applied minerals may prolong tree life and reduce yield losses.



Figure 31. Distinction between some symptoms of nutritional deficiencies and HLB.

⁵⁵ Corky veins may also be caused by CTV, B deficiency, girdling and borer damage.

In Australia, similar symptoms to those of HLB are caused by Australian citrus dieback (Broadbent et al. 1976, Broadbent 2000), and sometimes by blight (Broadbent et al. 1996), starch accumulation associated with B deficiency (see Haas & Klotz 1931a, b)⁵⁶ or winter yellows⁵⁷ (Broadbent & Fraser 1979), severe stem pitting strains of *Citrus tristeza virus* in grapefruit and *Phytophthora* root rot (Figs 32 to 42). Fruit re-greening symptoms of HLB can mimic symptoms of the rind of naturally re-greened Valencia orange fruit in late summer and autumn.



Figure 32. Australian citrus dieback-affected grapefruit leaves with asymmetric, sometimes dull, blotchy-mottling that crosses leaf veins (Pat Barkley).



Figure 33. Australian citrus dieback induced dieback and mottling of whole tree (left) and chlorotic leaf symptoms initially restricted to one branch (right) (Pat Barkley).



⁵⁶ Boron deficiency can cause vein corking (Haas & Klotz 1931a, b) as portions of cambium of the phloem disintegrate, and the xylem tissue to lesser extent, if at all. A copious amount of gum is formed, which finds its way to the exterior through a split in the cortex (Haas & Klotz 1931b) distinguishing this form of vein corking from the effects of HLB. Boron deficiency also leads to abnormal accumulation of carbohydrates. This, coupled with destruction of phloem, interferes with translocation (Haas & Klotz 1931b).

⁵⁷ Winter yellows results from starch accumulation in fully expanded late autumn flush (see Broadbent & Fraser 1979).

Figure 34. Small, rounded grapefruit and leaves with yellow veins (left), and off-season fruit of variable size (right) caused by Australian citrus dieback (Pat Barkley).



Figure 35. Off-season flowering (left and right) and yellow veins, and severe chlorosis (right) caused by Australian citrus dieback (Pat Barkley).



Figure 36. Severe Australian citrus dieback (left) and symptomatic grapefruit trees adjacent to native vegetation (right) (Pat Barkley).



Figure 37. Cold injury to sweet orange leaves at Kulnura, NSW, 2008 (left: GAC Beattie), and winter yellows on sweet orange at Griffith, 2008 (right: Pat Barkley).



Figure 38. Winter yellows in the Riverina (Pat Barkley).



Figure 39. Symptoms of girdling injury (GAC Beattie: Guangdong, late autumn 2008).



Figure 40. Chlorosis of leaves on a single branch of *M. paniculata* (left) caused by borer injury (right): Mundubbera – 17 November 2008 (GAC Beattie).



Figure 41. Left, vein corking caused by boron deficiency (GAC Beattie: Guangdong late autumn 2008)
Right, vein corking of West Indian lime leaves caused by citrus tristeza virus.



Figure 42. Root rot at Stanbridge, Riverina (Pat Barkley 2008).

Ultrastructural Changes

Matsumoto et al. (1961) recorded starch accumulation in HLB-infected leaves and Tirtawidjaja et al. (1965) described vein phloem collapse (hyperplasia and necrosis) and noted that it was associated with accumulation of starch in leaves⁵⁸. Schneider (1966, 1968a) observed that parenchyma cells of some HLB affected leaves are loaded with starch granules, causing leaves to have a leathery appearance and to retain moisture when removed from the tree. Localised pockets of necrotic phloem were scattered through the leaf vascular system of orange infected with African HLB (Schneider 1968a). The necrosis embraced the entire cross-section of the phloem of the leaf veinlets, but usually only a portion of the phloem in the main lateral veins, the midvein, the petiole, the leaf's base in the node, and occasionally in stems. The necrotic tissue was eventually compressed by enlargement of the parenchyma cells. There was massive accumulation of starch in the plastids, aberrations in cambial activity and in the subsequent differentiation of cambial derivatives, thickening of cytoplasm and increased staining of cell walls (by haematoxylin and safranin or lacmoid) and excessive phloem formation (Schneider 1968a). The HLB pathogen kills functional mature phloem. Schneider (1968a) suggested that grana and chlorophyll of the chloroplasts may be destroyed by being stretched due to enlargement of the granule within, and by being crowded against enlarging granules in other chloroplasts, giving rise to the yellow blotching symptom. Pockets of phloem necrosis did not appear in chlorotic shoots until leaves approached maturity.

Data presented by Achor et al. (2008) support development of HLB symptoms in the following sequence: phloem plugging and some collapse, sugar backup in localized leaf blade areas, starch accumulation until chloroplast structure is disrupted, chlorosis. They (Achor et al. 2008) found that starch accumulation occurred after phloem plugging and cell collapse and, therefore, localised phloem carbohydrate deficiency may have been a factor. Starch packing of chloroplasts did not rupture the outer membranes, but the inner grana structure was disrupted thus leading to chlorosis, but only in parts of the leaf where phloem plugging occurred. Sieve elements were obstructed by both amorphous and filamentous materials and both occurred in significant amounts, but bacteria were insufficient to cause plugging directly. The amorphous material was positively identified as callose by immunoassay with gold labelling. The positive identification of the filamentous material was presumed to be a phloem protein lectin.

⁵⁸ Matsumoto et al. (1961) referred to the disease as 'likubin'. Tirtawidjaja et al. (1965) called it 'citrus vein-phloem degeneration'.

Wu & Zhang (1985) observed, by electron microscopy, that the major cytopathic effect in the leaf vein of citrus infected with '*Ca. L. asiaticus*' was the presence of many cytoplasmic vesicles formed by the enlarged invagination of the plasma membrane, known as plasmalemmasome. These varied significantly in morphology and were observed in all types of cells. The second major cytopathic change was the aberration of the thylakoid membrane systems of chloroplasts; the grana lamellae were not well developed. The third change was the collapse of mitochondria. Su & Huang (1990) studied phloem disorganisation in likubin-affected Luchen, Ponkan and Tankan citrus leaves using light and electron microscopy. Starch accumulated in the chloroplasts. Starch grains also accumulated in xylem and phloem parenchyma cells progressively. At the same time, cambium became hyperactive (presumably as a defence reaction?) and produced large amounts of xylem and phloem elements (to bypass the blockage?). The cambium produced more phloem in the early stages. Vascular cells showed distortion, crushing, plasmolysis and necrosis. Finally disruption of vein epidermis appeared to be caused by hyperplasia of phloem elements. The degree of cytopathological damage was greatest in Tankan, where the primary xylem was extruded outside the epidermis as vein-corking.

Graft Transmission and Uneven Distribution of Pathogen in Tree

In 1937, Chen⁵⁹ Qibao hypothesised that Asiatic HLB was caused by a virus. In 1956 Lin Kongxiang demonstrated graft transmission of HLB (Lin 1963, Ke 1987). Variability in transmission is evident for the Asiatic pathogen as described in Lin & Lin (1990)⁶⁰, where information on early work on graft transmission in citrus was included. When diseased shoots were grafted on healthy rootstocks, 20% of those that survived exhibited HLB symptoms after 7 months. Also reported was an infection rate of 10% to 16% when shoots from asymptomatic twigs from sectorally infected mother trees were grafted onto healthy seedlings and an infection rate of 27% to 40% when shoots from symptomatic twigs were used. Symptom development was found to take 3 to 9 months. In a follow-up study, these results were apparently confirmed with an infection rate of 18% produced when budwood from asymptomatic twigs from diseased trees was used as grafting material and 30% to 35% infection when budwood from symptomatic twigs was used.

Capoor et al. (1974) reported a high percentage of transmission of '*Ca. L. asiaticus*' using bark or leaf-patch grafting. Tirtawidjaja (1972) found that pieces of bark gave only a very small percentage of transmission (3%). Bark with buds gave better results (26%). Leaf segments with mid-veins gave a much better chance for transmission than leaf segments alone (40%). Tips of twigs gave the best results (45%).

In trials with rough lemon and Cleopatra mandarins graft inoculated with '*Ca. L. asiaticus*', Tirtawidjaja (1972) showed that pieces of bark gave only a very small percentage of transmission (3%) of '*Ca. L. asiaticus*'. Bark with buds gave 26% infection, leaf segments with midvein gave 40% compared to 7% for leaf segments alone, and tips of twigs gave 45% transmission.

Zhao (1981) reported infection rates of '*Ca. L. asiaticus*' of 4.7% for stem bark, 67% for a piece of stem and 84% for a single bud when the graft tissue was sourced from the one infected tree. The rate of infection from grafting was found to increase when multiple grafts of diseased material were used as inoculum and to vary at different times of the year and with different host species or varieties.

⁵⁹ In Chinese names the surname is traditionally given first, and the given names, usually two, are written separately in some regions of Asia or as one word with two syllables. In both cases two initials should be cited in reference list (e.g., Zhao Xueyuan should be abbreviated as Zhao XY, and Huang Mingdu as Huang MD). If this is not done literature searches and citations will become increasingly difficult.

⁶⁰ An English translation of Lin (1956).

Schneider (1968a) suggested that the time interval between collecting propagative parts from diseased trees and grafting them to the test trees may be important. Similarly, Bové (2006b) recommended testing *Murraya* spp. immediately, without storage of samples.

Following infection, HLB symptoms can take some time to develop and spread throughout the tree, with infected trees often remaining asymptomatic for several months or more. Xu et al. (1988a) noted that symptoms of '*Ca. L. asiaticus*' in Ponkan mandarin seedlings developed 4 to 10 months after infection in experiments using *D. citri* nymphs and adults for disease transmission. Infected plants were held in greenhouses at temperatures between 24°C and 28°C. Capoor et al. (1974) reported that, after grafting with '*Ca. L. asiaticus*' infected plant material, symptoms were noted to appear within 8 weeks in summer and 10 weeks at other times of the year although, some test seedlings took 2 years or more to develop symptoms. Chinese box orange (*Atalantia buxifolia*: see Appendix I and Zhang et al. 2008) inoculated by '*Ca. L. asiaticus*'-carrying adults tested positive by PCR assays 3-4 months after inoculation, and 2-3 months after inoculation by grafting. Development of symptoms in the psyllid transmission tests was slower than that in graft transmissions and occurred sooner in sweet orange than in Chinese box orange (4-12 months) (Hung et al. 2001).

Biological indexing results of Martinez et al. (1971) also suggested uneven distribution of the '*Ca. L. asiaticus*' in diseased trees. Gonzales & Viñas (1981) also noted that '*Ca. L. asiaticus*' appears to be unevenly distributed in infected trees, possibly being confined to the twig or branch with symptoms in mildly infected trees, as diseased and disease-free scions were produced from an infected source tree. Field studies showed that the extent to which HLB affects a tree depends on the age of the tree at the time of infection and the population of insect vectors. The rapid spread of the disease within older trees appeared to be dependant not so much on internal movement of the pathogen but, more on infection of healthy branches by multiple feeding of infective vectors. Severely infected trees are either infected during propagation or by exposure to high populations of infective vectors after planting in the orchard.

Lin (1956) noted that the development of the disease was slower in mature trees. Zhao (1981) observed that, in young trees, only a few new shoots, usually at the top of the tree, became yellow initially and that symptoms subsequently appeared in branches below these shoots, then elsewhere in the tree. He (Zhao 1981) said that it may take 1 to 2 years for a whole tree to become infected.

Bassanezi & Bassanezi (2008) observed that in younger blocks the disease incidence and severity progress is faster than in older blocks. The factors that supported this were:

- more frequent and intensive new shoots in younger trees attracting higher population of *D. citri*, allowing higher infection rates; and
- small canopy size leading to relative higher initial severity of symptoms and faster distribution of the pathogen into the tree.

Huang (1979) found that '*Ca. L. asiaticus*' was unevenly distributed in partially affected trees and possibly confined to diseased branches showing symptoms. Distribution was more even in young shoots than in roots. By contrast, CTV was more evenly distributed in plants.

Gottwald et al. (2008) examined within-tree distribution of '*Ca. L. asiaticus*'. For trees that were displaying only very few HLB symptoms, there was a widely detectible and systemic distribution of '*Ca. L. asiaticus*' throughout the trees. However, by PCR assay, this systemic infection was not necessarily complete. This was interpreted by Gottwald et al. (2008) to indicate that most portions of the tree have '*Ca. L. asiaticus*' infection, i.e., the infection was completely or nearly completely

systemic, but the bacterial titre in individual portions of the tree may have been below the threshold of PCR detection. They stated that this may have implications for psyllid transmission.

Futch et al. (2008) found that 66% of the stumps of '*Ca. L. asiaticus*'-infected trees 180 days after chain-sawing off the canopy, contained one or more positive HLB sprouts. Not all sprouts on a given stump were positive for '*Ca. L. asiaticus*', thus providing evidence that the bacteria are not evenly distributed in the tree.

Sagaram et al. (2008) found a wide variation in concentration of '*Ca. L. asiaticus*' among tissues with the highest concentration in fruit peduncles.

While the African form of HLB is graft transmissible, the bacterium in the host plant is irregularly distributed and it is possible to produce a disease-free plant from an infected parent tree (McClellan & Oberholzer 1965b, Schwarz 1968a, McClellan 1970, Garnier & Bové 2000a). This presents problems for confirmation of diagnosis by DNA testing.

McClellan (1970) found that '*Ca. L. africanus*' does not readily pass to progeny trees propagated by bud from infected parents (4%), but more transmission occurs when scions are developed from larger propagative parts such as a piece of twig top-grafted to seedlings (64%). More positives occurred in trees propagated during January to April than during the spring and early summer. In partially diseased trees the HLB organism was found to occur only in sectors that showed symptoms and not in the normal parts. By contrast, van Vuuren (1993) found no difference between buds and grafts or increasing the number of buds on transmissibility, but noted that uneven distribution of the HLB pathogen and low titre because of climatic conditions, could contribute to a low transmission rate, in which case higher transmissions would be achieved by using stem pieces. There was a difference in transmissibility of HLB from different citrus growing regions. van Vuuren (1993) also reported that South African HLB isolates can move 30-50 cm downwards in a tree in 12 months.

Schneider (1968a) attributed the erratic nature of transmission of the African HLB pathogen to where the pathogen multiplies. If the site of pathogen activity is where phloem necrosis occurs, the pathogen may soon be isolated by hypertrophy and hyperplasia of surrounding parenchyma cells. Alternatively the petioles abscise or are cut off before grafting and there is more inoculum in the petiole than in the stem.

Seed Transmission

Reduced fruit production is a common symptom of HLB, and many seeds are aborted or are small and dark. Capoor et al. (1974) reported no evidence of seed transmission of '*Ca. L. asiaticus*' when seeds from fruits of infected grapefruit and sweet orange were grown. A large number of seeds from symptomatic fruit and both normal looking and brown and abortive seeds were used in the study. However, Tirtawidjaja et al. (1981) suggested that some stunted, chlorotic plants were produced by seeds from small fruits produced by HLB infected trees, but noted that further work was required to clarify the results. No symptoms were seen in seedlings grown from seed from normal sized fruit produced by diseased trees. Ke et al. (1988) found no symptoms in seedlings grown from 888 Fuji ('*C. tangerina*', a form of *C. reticulata*) seeds from HLB trees observed over 5 years. Sagaram et al. (2008), using PCR, found that '*Ca. L. asiaticus*' was distributed in bark tissue, leaf midrib, roots, and different floral and fruit parts, but not in endosperm and embryo, of infected citrus trees.

Zhou et al. (2008a) detected '*Ca. L. asiaticus*' in up to 53% of all seeds tested both from HLB-infected periwinkle (*Cantharanthus roseus*) and dodder (*Cuscuta pentagona* Engelm.) without

resorting to nested PCR. The PCR amplicons were confirmed by sequence analysis. Germination rates of these '*Ca. L. asiaticus*'-positive seeds from both plant species were normal. Over 80% of the periwinkle plants germinated from the infected seeds showed initial HLB symptoms of vein yellowing and leaf yellowing only when they were stressed by nutrient deficiency. Surprisingly, the disease progressed slowly, and did not cause plant death, and all symptomatic plants became asymptomatic after the stress was removed. The '*Ca. L. asiaticus*' titre remained very low; in most cases, detected only by nested PCR or regular PCR by increasing the concentration of the bacterial DNA. The periwinkles infected with '*Ca. L. asiaticus*' via seed transmission were maintained for over six months. Zhou et al. (2008a) suggested that although '*Ca. L. asiaticus*' was transmitted in periwinkle seeds a second, undescribed component of an HLB disease complex was not.

In the October 2007 Environmental Assessment Final Rule for Movement of Commercially packed Citrus Fruit from the Citrus Canker Quarantine Areas under IV Environmental Impacts it states 'we have received reports of preliminary scientific evidence indicating that when seedlings are generated from seed that is taken from plants infected with citrus greening, a small percentage of those seedlings are themselves infected with citrus greening. In response to this and to be abundantly cautious, APHIS has amended the Federal Order for citrus greening to prohibit movement of seed for planting from areas quarantined for citrus greening'.

Hartung et al. (2008) germinated seeds from '*Ca. L. asiaticus*' symptomatic fruit of '*Murraya paniculata*', rough lemon and Meyer lemon, sour orange, grapefruit and Valencia sweet orange and kept 319 seedlings in a greenhouse for nearly 3 years. The seedlings were observed regularly for symptoms of HLB and tested for '*Ca. L. asiaticus*' by Q-PCR three times using a 16S rRNA based procedure. The large majority of seedlings did not show symptoms, and none of the seedlings tested positive for '*Ca. L. asiaticus*' by a real-time PCR. However, 9 of 89 sour orange seedlings showed abnormal growth patterns, which included stunting, defoliation and chlorosis. One of these sour orange seedlings in particular was severely stunted and showed symptoms similar to HLB. In the abstract of this paper, the authors stated that 'This seedling was positive for the presence of '*Ca. L. asiaticus*' when tested with a different set of primers that targeted the 16S region '*Ca. L. asiaticus*'. The amplicon was sequenced from duplicate reactions and was found to have a 100% match to the 16S gene sequence from several strains of '*Ca. L. asiaticus*' deposited in Genbank.' Yet in his talk when the paper was presented, Hartung claimed there were **no positive PCRs, no symptoms and therefore no seed transmission**. Certainly the photograph of the sour orange seedling that was shown, suggested a tetraploid or a zygotic seedling, rather than a sour orange with HLB symptoms.

Shatters (2008) observed HLB-like symptoms in seedlings of Duncan grapefruit grown in insect-free controlled environment greenhouses. Using a newly developed qPCR-based method for the detection of '*Ca. L. asiaticus*' 16S rDNA sequence, he was able to detect the '*Ca. L. asiaticus*' sequence in less than 10% of these seedlings; however, the detection of '*Ca. L. asiaticus*' did not necessarily correlate with symptoms. In subsequent studies with Ruby Red grapefruit and Hamlin orange, the 16S rDNA sequence was detected in seedlings that were surface sterilised and germinated in sterile Magenta jars (Shatters 2008). Sequence analysis of the 16S rDNA sequence indicated that the amplified DNA was 100% identical to previously reported '*Ca. L. asiaticus*' sequence and only 98% of the bases were identical to '*Ca. L. americanus*'. Dissection of the sterile-grown seedlings showed that the highest detectable level of '*Ca. L. asiaticus*' was in the seedling roots. As plants grew, HLB-symptomatic plants developed more slowly than asymptomatic plants, however, **most lost HLB symptoms over time**.

Graham et al. (2008) reported that seed coats of Pineapple sweet orange seeds from infected fruit in late autumn 2006 in Florida contained high titres of '*Ca. L. asiaticus*', based on real time (RT-) PCR assay. Seeds minus their seed coats were germinated. All surviving seedlings from seed with RT-PCR positive seed coats, as well as 45 plants with negative seed coats, were sampled and tested by RT-PCR. From the 59 plants sampled, 7 plants were either positive or questionably so. Ct values for one plant were 28.22 and 31.38 for a second plant. Ct values for the remaining suspect plants

were between 32.3 and 33.4 (a Ct value between 30 and 32 was considered questionable for HLB). Upon re-assay, 3 of the 7 plants were positive and yielded ~700 bp 16s rDNA sequences for '*Ca. L. asiaticus*' after nested PCR (Benyon et al. 2008). The three plants testing positive were transferred to the UDSA-ARS facility in Fort Pierce to conduct psyllid transmission studies, so as to partially fulfill Koch's postulates. Of these three plants, only one tested positive in subsequent RT-PCR testing. In addition to the 59 plants tested, 356 plants not tested in the original group of 56 were tested and none were positive or questionable. In late autumn 2007, fruit were collected from 8 symptomatic trees. Extracted seed was classified as healthy (28%), off coloured-gummy (29%) or aborted (43%). Healthy (359) and off-coloured (344) seed were planted and the resultant 723 seedlings were assayed by RT-PCR in February 2008. Six had Ct values less than or equal to 32 after two assays. In 2008, HLB was confirmed for two Carrizo citrange seed source trees in a Florida citrus nursery. From each positive tree, fruit were collected for extraction and germination of at least 200 seedlings. In seedlings assayed by RT-PCR for transmission, 142 seedlings from the first source yielded two seedlings with Ct values of 32 or less, and of 148 seedlings from a second source, 5 seedlings had Ct values of 32 or less. **The conclusion was that transient infection of seedlings with '*Ca. L. asiaticus*' had occurred** (Graham et al. 2008). Confirmation of seed transmission clearly requires:

- multiple primers for various loci; and
- psyllid and graft transmission of the pathogen initially found in seed (Graham et al. 2008)

Heat treatment of seed should be an essential requirement for entry of citrus seed from any country with HLB.

Dodder Transmission

'*Ca. L. asiaticus*' has been transmitted experimentally by dodder (*Cuscuta* spp. [Solanales: Convolvulaceae]) from pathogen-infected citrus to:

- citrus and periwinkle (*Catharanthus roseus*) by *Cu. australis* R. Br. (Tirtawidjaja 1981, Subandiyah 1994);
- periwinkle by *Cu. campestris* Yuncker (syn.) (Garnier & Bové 1983, Ke et al. 1988b, Olfato et al. 1990, 1991);
- tobacco (*Nicotiana tabacum* L. [Solanales: Solanaceae]) by *Cu. campestris* (Garnier & Bové 1993);
- tomato (*Solanum lycopersicum* L. [Solanaceae]) by *Cu. pentagona*⁶¹ Engelm. (Duan et al. 2008); and
- orange jasmine by *Cu. pentagona* (Zhou et al. 2007).

Garnier & Bové (1983) also reported transmission of '*Ca. L. africanus*' from citrus to periwinkle by *Cu. campestris*.

'*Ca. L. asiaticus*' can multiply and spread within infected *Cu. ceanothi* Behr (syn. *Cu. subinclusa* Dur. & Hilg.), *Cu. campestris*⁶² (Ghosh et al. 1977) and *Cu. australis* (Su & Huang 1990)⁶³. Ghosh et al. (1977) observed that the pathogen multiplied more favourably in dodder on diseased sweet orange (which they assumed to be a natural host of the pathogen) and suggested this as evidence that it could be possible to use dodder as an alternative host of the pathogen. Zhou (2008) reported

⁶¹ They (Garnier & Bové 1983) also used '*Ca. L. africanus*'.

⁶² Possibly *Cu. australis*, not *Cu. campestris*. See next footnote.

⁶³ For recent information on synonyms within the genus *Cuscuta* see: O'Driscoll CW. 2003. Preliminary review of the genus *Cuscuta* in North America. Prepared for the NAPPO PRA Panel – July/August 2003. North American Plant Protection Organization. 10 pp. <http://www.nappo.org/PRA-sheets/CuscutaTable2003.pdf>. Although she lists *Cu. pentagona* as a synonym of *Cu. campestris* evidence presented by Stefanović et al. (2007) indicates that it is not.

that infected *Cu. pentagona* plants did not exhibit symptoms of HLB even when they contained high titres of 'Ca. L. asiaticus'.

Zhou et al. (2008) observed normal germination rates for periwinkle and *Cu. pentagona* seeds from plants infected by 'Ca. L. asiaticus' and the pathogen was detected in up to 53% of all seeds of both hosts⁶⁴.

Halbert & Manjunath (2004) considered natural transmission of HLB by *Cuscuta* spp. unlikely. However, there is a possibility that natural and anthropogenic dispersal of species such *Cu. australis* and *Cu. campestris* may have contributed to the spread of several pathogens known to be transmitted by them, including HLB. Dodder is a common parasite of a broad range of plants in Asia (Browne 1968, Rajak et al. 1985, Abu-Irmaileh 1987, Abu-Irmaileh & Fucik 1989, Banerjee et al. 1993). Citrus pathogens other than those that cause HLB can also be transmitted by dodder. These include transmission by *Cu. reflexa* Roxb. in India of citrus yellow corky vein (Reddy & Naidu 1989), a viral ringspot disease of citrus (Byadgi & Ahlawat 1995), and a badnavirus associated with citrus mosaic disease (Ahlawat et al. 1996).

Recorded rutaceous hosts of dodder species in laboratory and field observations include *Citrus* species and hybrids (Abu-Irmaileh 1987, Abu-Irmaileh & Fucik 1989, Byadgi & Ahlawat 1995, Ahlawat et al. 1996, Pant & Ahlawat 1998), bael (*Aegle marmelos* (L.) Corr. [Aurantieae] (Rajak 1985), and toothpick glycosmis (*Glycosmis trifoliata* (Blume) Spreng. syn. *Glycosmis pentaphylla* (Retz.) DC. [Clauseneae]) (Banerjee et al. 1993).

Fig. 43 shows dodder-covered beds of citrus seedlings in a citrus nursery in Pakistan July 1996. Budwood for propagation of the seedlings was sourced from an adjacent block of trees in which HLB was prevalent.



Figure 43. Dodder (*Cuscuta* sp.) covering citrus seedlings in a citrus nursery at Sargodha in Punjab Province, Pakistan, in July 2006 (GAC Beattie).

Seeds can persist in soil, and are often planted with contaminated seed (O'Driscoll 2003). Some species have very broad host ranges, and host can vary from cereals, lucerne, clover, herbs, vegetables (e.g., carrot, celery, potato, capsicum and eggplant), flax, linseed, shrubs, and trees (Knorr 1949, Rajak et al. 1985, Abu-Irmaileh 1987, Abu-Irmaileh & Fucik 1989, Banerjee et al. 1993, O'Driscoll 2003, Stefanović et al. 2007).

⁶⁴ Zhou et al. (2008) also noted that over 80% of the periwinkle plants that germinated from the infected seeds showed initial HLB symptoms of vein yellowing and leaf yellowing only when they were stressed by nutrient deficiency, and that the disease progressed slowly, and did not cause plant death. Furthermore, all symptomatic periwinkle plants became asymptomatic after the stress was removed. These and other results suggested that although 'Ca. L. asiaticus' was seed transmitted, a second, undescribed component of an HLB disease complex was not.

The genus *Cuscuta* comprises some 165–175 currently described species⁶⁵. It is nearly cosmopolitan in distribution with species found on every continent (except Antarctica), ranging from 60° N to 47° S (Stefanović et al. 2007). The vast majority of species of *Cuscuta* only occur in the Americas with Mexico and adjacent regions as a centre of diversity. Despite their wide cosmopolitan distributions, *Cu. australis* and *Cu. campestris* (one of the most successful parasitic weeds), are of North American origin.⁶⁶

Potential Transmission by Dodder Laurel

In addition to transmission of HLB by *Cuscuta* spp., transmission by another parasitic plant, dodder laurel (*Cassytha filiformis* L.⁶⁷ [Magnoliales: Lauraceae]) may prove possible. This possibility is based on reports of successful transmission of citrus mosaic (Reddy et al. 1985), CTV (Reddy & Murti (1988), citrus yellow corky vein (Reddy & Naidu 1989), and of a mycoplasma-like organism from coconut (*Cocos nucifera* [Arecales: Arecaceae]) to periwinkle Saskikala et al. (1989). Fig. 44 shows Chinese box orange covered with *Cassytha* sp. in Hainan.



Figure 44. Dodder laurel (*Cassytha* sp.) covering Chinese box orange (*Atalantia buxifolia* (Poir.) Oliv.) in a conservation reserve in coastal Hainan in October 2008 (GAC Beattie).

HLB Epidemiology

Natural transmission is related to high vector populations and the extensiveness of the inoculum reservoir (Aubert 1987c, Chao et al. 1979). Psyllid migrations appear to be highest when plants are flushing; psyllid populations are sedentary and feeding when foliage is mature (Aubert 1987c, Catling 1969a).

The time-lag between transmission of the pathogen by psyllid vectors or by propagation and the onset of visual symptoms for Asian and African HLB can be quite variable depending on the time

⁶⁵ All members of the genus are vines with twining, slender, pale stems, with reduced, scalelike leaves, and no roots. They become attached to stems by haustoria and depend almost entirely on their hosts to supply water and nutrients (Stefanović et al. 2007). Most species have reduced amounts of, or no, chlorophyll (Stefanović et al. 2007). They divert sugars from the host crop, weakening plants and often causing total failure to set fruit.

⁶⁶ The monophyletic nature of these species, nested within a clade with narrow distributional ranges, led Stefanović et al. (2007) to conclude that their physiological capability to use hundreds of genera as hosts probably arose once, in their common ancestor. This capability thus allowed them to spread over large geographic areas, either naturally or as consequence of anthropogenic influences. Stefanović et al. (2007) concluded that there was little doubt that the initial jump in dispersal and speciation had to occur from the Old World, most likely Africa, to the New World, with the first major split and subsequent diversification of *Cuscuta* species in the New World most likely occurring between South America and Mexico. They regarded Mexico as the centre of biodiversity for *Cuscuta* and a staging ground for subsequent diversification.

⁶⁷ *Ca. filiformis* is a leafless, climbing, twining, vine-like, autoparasitic and plant-hyperparasitic phanerogam. It is indigenous to Hawaii and infests a wide variety of plants, mainly woody hosts, including plants of agricultural and economic value, throughout the tropics worldwide. It belongs to a genus with about 20 species, and occurs in Australia. Hosts of economic importance include citrus, and it may cover and parasitise dozens of host species simultaneously (Nelson 2008).

of the year when infection took place e.g., environmental conditions, tree age, and species/cultivar, (McLean & Oberholzer 1965b, Catling & Atkinson 1974, Zhao 1981, Aubert 1987b, Gottwald et al. 1991b). It can be rapid (Fig. 45). It appears that the same may be true for the '*Ca. L. americanus*' isolate (Bergamin-Filho et al. 2008). Thus quantifying the severity or expression of disease symptoms in individual trees may not be a precise indication of pathogen content. Additionally, due to temporal variation in symptom expression, trees infected at the same time may express the onset of symptoms with great variability over one or more years. Time-lag between infection and symptoms may be 3 months to 2-3 years (Lin 1956, Zhao 1981, Xu et al. 1988a, Capoor et al. 1974, Hung et al. 2001, Gottwald et al. 2007). Thus symptoms are expressions of infections that may have occurred over multiple years.

Bassanezi & Bassanezi (2008) found that in young blocks, disease incidence and severity progress was faster than in older blocks. The factors that support this were:

- more frequent and intensive new shoots in younger trees attract higher population of HLB psyllid vector that allows higher infection rates; and
- small canopy size leads to relative higher initial severity of symptoms and faster distribution of the pathogen into the tree.

The HLB incidence progress curves were well described by the Gompertz model (Bassanezi & Bassanezi 2008). Disease incidence reached 50% in less than 2 years after the appearance of first symptomatic trees in 0-2 year old blocks, and in about 10 years after the appearance of first symptomatic trees in blocks older than 10 years. For trees in which the first symptoms occurred when they were 0-2 years old, it took about 2 years for the HLB severity to reach 100%, while it took about 12 years for trees in which the first symptom onset occurred when they were older than 10 years (Bassanezi & Bassanezi 2008). Disease incidence and severity estimated every year were used to estimate the total disease severity in the affected citrus block estimate the relative yield (*RY*) of the affected citrus block compared to yield of healthy citrus block. With this approach they (Bassanezi & Bassanezi 2008) estimated *RY* in citrus blocks without any HLB control measures for each year depending on the age of citrus trees at HLB symptom onset. By multiplying the estimated *RY* by expected yield of healthy groves for each year, it was possible to estimate the impact of HLB on yield under no disease control. Without adoption of HLB control measures, citrus blocks infected up to 5 years old would have considerable yield reduction about 2 to 4 years after the onset of the first symptomatic trees. However, for older citrus blocks, the yield reduction would be significant 5 to 10 years after the first symptoms.

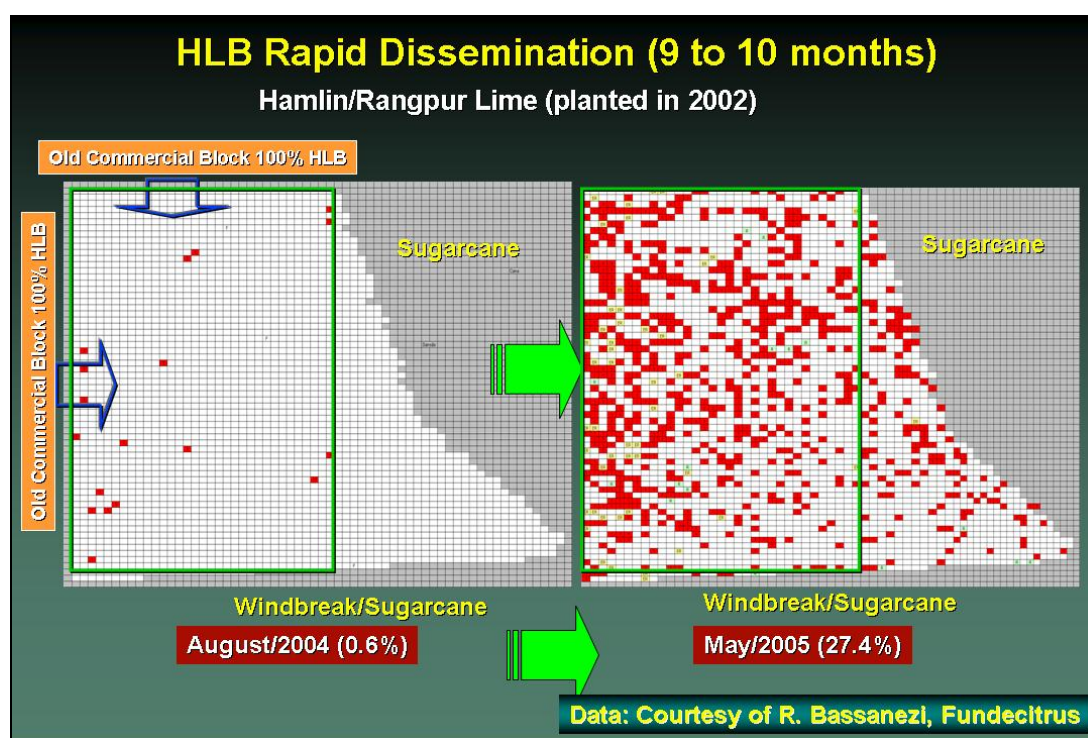


Figure 45. Rapid dissemination of HLB over 9-10 months from a 100% infected orchard to an adjacent orchard in Brazil (T Gottwald: Citrus HLB Research Overview for NAS/ARS Combined Workshop, 2007).

Spatial and temporal dynamics of HLB were investigated by Gottwald et al. (1989, 1991a, b, 2006a,b, 2007), in plots in Réunion and southern China to estimate the rates of disease increase and expected longevity of infected sweet orange and mandarin groves infected with 'Ca. L. asiaticus'. The investigations showed that HLB epidemics are multi-year in duration and rarely progress to an asymptote before removal of the planting occurs. In one location in China (Gottwald et al. 1991a), the LCF plot (Liuzhou Citrus Farm, Guangxi) in Fig. 46, an asymptote was reached after 13 y. But for groves that became unproductive and were removed, disease incidence only reached 0.76 (76%) after 6 y (LARI: Liuzhou Agricultural Research Institute) and 0.84 (84%) after 9 y (RI: Réunion), but the logistic model predicted asymptotic disease levels (0.99 or 99%) after 7 y and 13 y for these plots respectively (Gottwald et al. 1989, Gottwald et al. 2007).

Typical behaviour of *D. citri* is to jump when disturbed, followed by a short landing flight of 3-5 m, with resulting aggregative populations and clusters of HLB infected trees (Aubert 1990b). Within local areas, aggregations of infected trees occur that at times can be quite large (Gottwald et al. 2007). In such cases vectors apparently spread the disease to either adjacent or nearby trees. For example, in Florida, 90% of asymptomatic, but RT-PCR positive, trees were within 38 m of visually symptomatic trees (Irey et al. 2006). This supports the findings of spatial autocorrelation that the establishment of secondary foci is within 24 m to 50 m (Gottwald et al. 1991a). The general pattern of aggregations can be strongly correlated with the usual traffic paths in orchard, especially in high density plantings (Aubert 1990b, Gottwald et al. 1991a).

In Brazil, HLB has been estimated to move 12 km per year (Gottwald et al. 2007) and possibly up to 19 km to 24 km per year. Growers believe it takes 3-15 months from infection to symptoms in Brazil. Symptoms are mostly in orchards 8+ years old (Bassanezi et al. 2006). Bassanezi et al. (2007) showed that there is mild aggregation of HLB symptomatic trees in Brazilian orchards. Secondary foci were spread all over the block indicating that there is long (4-22 tree spaces distant) and short (to nearby trees) dispersal. This impedes adoption of an eradication radius of exposed trees and the entire block would need to be eliminated.

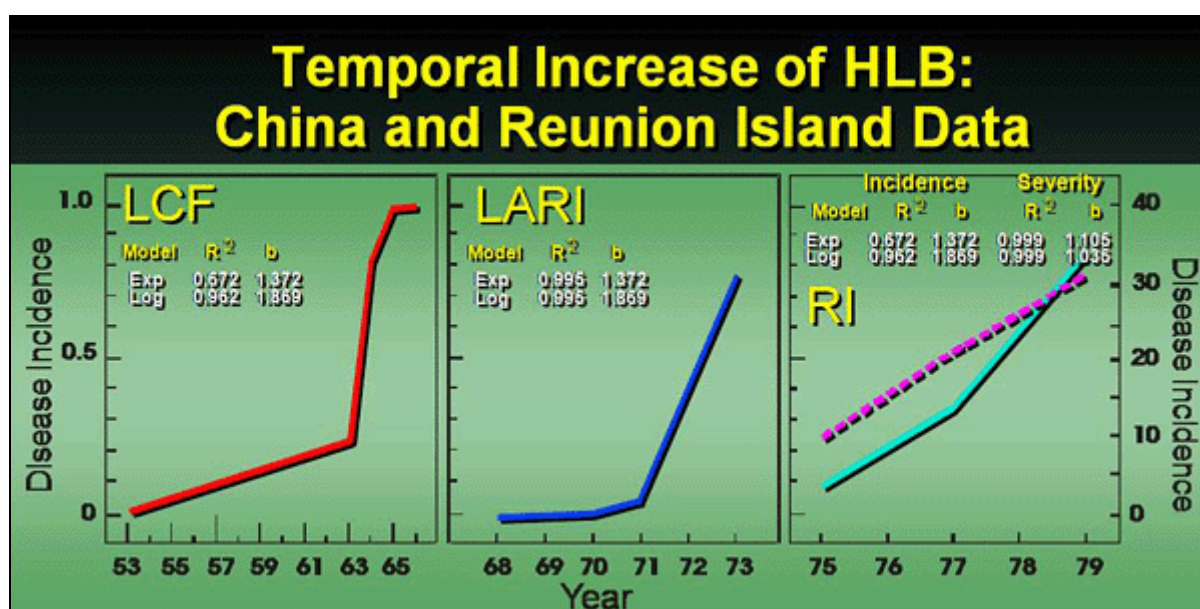


Figure 46. Analysis of disease progress of citrus huanglongbing in citrus groves in the People's Republic of China and Réunion Island. LCF = Liuzhou Citrus Farm Plot located near Liuzhou City, Guangxi Province, People's Republic of China. LARI = Luizhou Agricultural Research Institute, Guangxi Province, the People's Republic of China; RI = Réunion Island; R² coefficient of determination; *b* = slope of regression. Disease percentages were transformed by $\ln(y)$ and $\ln(y/(1-y))$ for exponential (EXP) and logistic (LOG) models, respectively (Gottwald et al. 1989, Gottwald et al. 2007).

Bergamin-Filho et al. (2008) related the number of insecticide sprays with HLB incidence, in a commercial orchard in Brazil. A total of 716,476 orange trees, from 5 to 10 years old, distributed in 357 blocks were submitted to a different number of insecticide sprays (3 to 12) during three growing seasons (2004/2005, 2005/2006, and 2006/2007). Eradication of symptomatic trees was carried out in the whole area 4 to 8 times per growing season. Incidences of HLB in all blocks ranged from 0% to 8.35 % of symptomatic trees. There was no negative relationship between the number of sprays and HLB incidence (eradicated plants), considering each one of the three growing seasons. No relationship was also observed between the average number or the total number of insecticide sprays per block and the eradicated plants in the last season (to minimise the influence of a long latent period). These results suggest that, the low incidence of HLB was mainly due to eradication of symptomatic trees rather than to insecticide sprays. The grouped blocks with the highest rates of disease progress were close to another farm, which had no management of the disease and served as source of inoculum. Insecticide sprays did not prevent HLB-bacteria transmission by infectious psyllids from this external source. The grouped blocks with the lowest final incidences were located in the centre of the farm.

Gottwald et al. (2007) and (Halbert et al. 2008) speculated that infected *D. citri* may have been carried 67 km to 145 km across the Everglades in Florida from heavily infected urban areas along the coast to the eastern borders of the citrus groves. Although not conclusive, this long-distance movement may have been related to air masses during hurricanes or tropical storms (Gottwald et al. 2007, Halbert et al. 2008).

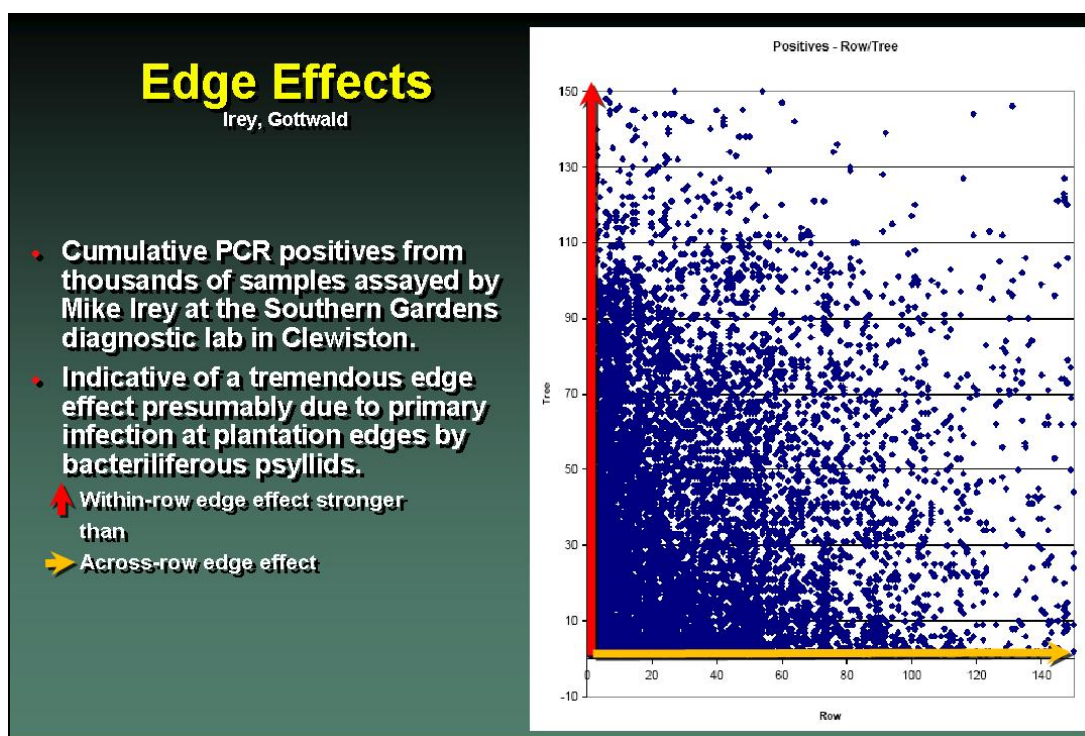


Figure 47. 'Edge effect' of HLB infection stemming from ingress of *D. citri* from an adjacent HLB infected orchard (T Gottwald: Citrus HLB Research Overview for NAS/ARS Combined Workshop, 2007).

Gottwald et al. (2008a) used stochastic modelling to give likelihood estimates of the 'primary infection rate' (introduction from outside the area under study) and 'secondary infection' (spread locally within the area of study) over a large contiguous planting of citrus 4856 ha in South Florida. The area was completely surveyed in a 100% census of trees five times over a 2-year period. The overall interpretation was that there are two spatial processes that are ongoing during HLB epidemics, but not necessarily simultaneously. Background or primary spread of disease that originates from outside the plot areas is the most hazardous kind of spread in that it indicates a spatial process of long distance or regional vector transmission (Fig. 46). No amount of spraying will stop psyllids from feeding on distant HLB-positive sources, migrating to uninfected trees at some distance, and transmitting the bacterial pathogen before they die from insecticide applied to the new trees they settle on. Secondary spread is characterized by vector transmissions that are not to nearest neighboring trees, but rather to trees that are nearby within a local area of influence. HLB spread occurs as an incessant mixture of these two processes with a continuous introduction of inoculum from outside the plot and local spread from within the plot occurring simultaneously. Gottwald et al. (2008b) used survival analyses to explore the contribution of short distance transmissions of HLB by psyllids and the influence they have on the overall spatial pattern of disease that develops through time. The goal was to examine the threat of HLB-infected trees to other trees within the planting. The influence of 'distance' from prior HLB-symptomatic trees in the near vicinity or even within the block in general did not contribute greatly to 'survival', i.e., the probability of remaining disease free. Thus this study confirms that the overarching influence in HLB epidemics is the migration and transmission of '*Ca. L. asiaticus*' via psyllids from outside the block, i.e., the influence of primary spread. It also indicates that attempting to control HLB locally is probably futile. Significant control will likely only be achieved from regional disease management strategies⁶⁸.

⁶⁸ This will be difficult in Australia eg Riverina, and Riverland where citrus orchard size is small.

Especially during assessments of early incidence, there is a higher incidence of HLB at the edges of the grove and associated with roads, canals, ponds. This higher than expected accumulation is described as an 'edge effect' related to psyllid movement and migration (Gottwald & Irey 2008).

Detection

Refer to the draft PHA Diagnostic Protocols for HLB by Hailstones & Holford for PCR methodology to be used during an incursion.

Other methods used to detect the pathogens have included light microscopy (Tirtawidjaja et al. 1965, Schneider 1968, Heredia et al. 2006), the iodine starch test (Le & Nguyen 2002, Onuki et al. 2002), electron microscopy and ELISA (monoclonal antibodies, MA), but detection methods based on polymerase chain reaction (PCR) and DNA hybridisation are at present the most successful methods available (Bové & Garnier 2003, Halbert & Manjunath 2004).

Symptomatology

Field recognition of HLB, based on visual symptoms (see above), requires well trained personnel (Bové 2006b).

Carlos et al. (2006) and Dixon (2008) reported a simple aid for the identification of suspect HLB symptoms; use a pen to draw two circles symmetric about the leaf mid rib, and compare the leaf colour within the two circle — if one is yellow, and one green, it could be HLB. Dixon (2008) suggested that 95% of samples collected using this test should be PCR positive for HLB.

Spectral Characteristics

Hyperspectral imaging may have the potential to detect HLB. A FieldSpec spectroradiometer (350 nm to 2500 nm) was used by Mishra et al. (2007), to detect HLB-infected trees. It was found that the spectral bands of green to red and near infrared have the ability to discriminate between HLB-infected trees from healthy trees. These wavelength regions include green peak wavelengths at around 530 nm to 564 nm, 710 nm to 715 nm (red edge), and near infrared wavelengths of 1041 nm and 2014 nm.

The results of a study by Poole et al. (2008), suggest that it is unlikely that the visible near-infrared (400 nm to 1000 nm) portion of the electromagnetic spectrum alone will be able to differentiate HLB infected plants from plants that are compromised by some other biological stress.

Biological indexing

Biological indexing (Roistacher 1991, Frison & Taher 1991, Schwarz 1968) to citrus indicators takes 6 months. Transmission is best achieved by side shoot and approach grafting and least with leaf pieces (Lee et al. 1990): see also the earlier section on graft transmission on page 80. At the first detection of HLB, side shoot grafting to sweet orange indicator plants should be carried out for HLB (Okuda et al. 2005). A battery of indicator plants should also be used to determine if other

graft transmissible pathogens are present, as a possible indication of illegal importation of budwood.

Iodine Starch Test (IST)

The iodine starch test or 'scratch method' used by Takushi et al. (2007), is based on the observation by Schneider (1968) that significant accumulation of starch occurs in HLB affected leaves and the finding by Kawano (2006) that the average quantity of starch of three citrus cultivars was 514.2 mg/kg in HLB affected leaves and 85.6 mg/kg in healthy leaves (t -test $p < 0.01\%$). Takushi et al. (2007) demonstrated that the scratch method (using 50 mM of iodine solution), and PCR were more than 90% in agreement. They also reported that this method did not give HLB-positive reactions for healthy, nutrient-deficient or other diseased leaves.

Accumulation of starch granules in HLB-infected leaves evidenced by an iodine reaction (Onuki et al. 2002) was shown to give 8.9% false negatives and 3.0% false positives when compared to PCR tests (Le & Nguyen 2003).

Taba et al. (2006) claimed the IST test is a rapid, simple, portable and inexpensive test that can be used in the field to complement visual diagnosis and differentiate HLB symptoms from mineral deficiencies.

Eng (2007) found that the accuracy of the scratch test ranged from 74.5% to 89.5% for mandarins and for pomelo, from 12.5% to 51.7%, dependent on the correct selection of infected leaves.

Albrecht & Bowman (2008) confirmed substantial amounts of starch in chloroplasts of HLB-affected leaves and found that most noticeable among the large number of differentially expressed genes related to metabolic processes in HLB-infected leaves were those for the large subunit of ADP-glucose pyrophosphorylase, the key enzyme catalyzing the first and limiting step in starch biosynthesis. Thirteen to 17 weeks after inoculation transcript levels for alpha-amylase, one of the enzymes involved in starch mobilisation, increased more than four-fold. Transcript levels for several glycosyl hydrolase family proteins, cellulose-hydrolyzing enzymes controlling various aspects of plant development, increased more than nine-fold. Among the genes down-regulated nearly four-fold and two-fold, respectively, were beta-amylase, a key-enzyme in starch degradation, and sucrose-phosphate synthase, a key enzyme involved in the regulation of sucrose synthesis in the cytoplasm (Albrecht & Bowman 2008).

The up-regulation of three key starch biosynthetic genes including ADP-glucose pyrophosphorylase (AGPase), starch synthase, granule-bound starch synthase and starch debranching enzyme apparently proceeding unaltered, together with restricted movement of sucrose from leaves due to phloem plugging, likely leads to accumulation of starch in HLB pathogen infected leaves. The disturbed sucrose transportation resulted from the plugged sieve pores rather than the HLB bacterial aggregates since '*Ca. L. asiaticus*' does not form aggregate in citrus. The up-regulation of *pp2* gene is related to callose deposition to plug the sieve pores in HLB pathogen infected plant (Kim et al. 2008, 2009).

During 2007 and early 2008, leaf samples were collected from 1759 HLB suspect trees. For each tree, the predominant symptom type on the tree was noted and leaf samples were tested using the starch test and real time PCR (RT-PCR). Over all samples collected from the symptomatic trees, 85% of the samples were positive by RT-PCR versus 78% positive for the starch test. The starch and the RT-PCR tests agreed for 76% of the samples. There did not appear to be substantial differences in the correlation between the tests during the months of July and February, but there was a difference in

the correlation between the two tests in June. No difference between early-midseason and Valencia varieties with respect to the correlation between the two types of tests was found, but there was a difference between the various symptom types. The best correlation between the tests was obtained for leaves exhibiting the classic blotchy mottle leaf symptom and the worst correlation was obtained with leaves showing the green island symptom type. Overall, the RT-PCR testing was more consistent in detecting HLB infected trees than the starch test. Therefore, the starch test should be considered a useful tool for HLB diagnosis in the field, but not as a substitute for PCR-based testing (Chamberlain & Irey 2008).

Koizumi et al. (1994) did not find staining with aniline blue or DAPI⁶⁹ to be reliable for detecting HLB affected cells in citrus.

Caution is needed to ensure that a positive IST is not caused by factors other than HLB, particularly Australian citrus dieback, CTV, winter yellows, boron deficiency, girdling and borer damage.

Gentisyl-β –glucose

Schwarz (1965, 1968) reported a fluorescent substance (gentisyl-β–glucose) in ether extracts of HLB (*'Ca. L. africanus'*) affected bark. By paper or thin layer chromatography (TLC), a bright blue spot fluoresces at 365 nm. The same fluorescence can be seen in the albedo of *'Ca. L. africanus'* affected fruits and was found to be reliable for early detection, but not in cultivars such as rough lemon or trifoliate orange. McClean (1970) found evidence that indicated that the method is unreliable for detecting latent infection of *'Ca. L. africanus'* in nursery trees.

Feldman & Hanks (1969) showed that this test was not specific for *'Ca. L. africanus'* and produced positive results with some healthy citrus and with stubborn and Australian citrus dieback affected fruits. Hooker et al. (1993) re-evaluated the reliability of the fluorescent marker gentisic acid (GeA), to predict presence of *'Ca. L. asiaticus'* and *'Ca. L. africanus'* and found that the method was reliable when GeA levels were above 300 µg/gm of tissue and when used in combination with other diagnostic criteria under glasshouse conditions. Wulff (2006) found a good correlation between TLC and PCR in samples infected by *'Ca. L. americanus'*, but not *'Ca. L. asiaticus'*.

Monoclonal Antibodies

From around the mid 1980s monoclonal antibodies (MA) were used to detect the presence of HLB pathogens, but proved to be too specific for use in general diagnosis of the disease (Garnier et al., 1991, Gao et al. 1993).

Electron and Light Microscopy

Electron microscopy was found to be the most reliable method of detection of the HLB pathogens until 1992. It allowed the pathogens to be observed in the sieve tubes of infected citrus leaves, but could not distinguish between Asian and African strains (Laflèche & Bove 1970 a,b, Saglio et al. 1971, Moll & Martin 1974, Garnier & Bové 1977, Moll et al. 1980, Varma et al. 1993). *'Ca. L. americanus'* was visualised in citrus phloem (Tanaka et al. 2004, 2006) and in phloem vessels of experimentally infected periwinkle by scanning electron microscopy (Tanaka et al. 2007). Electron microscopy was based on two basic properties of the HLB bacteria: they were exclusively located

⁶⁹ Musetti R, Favali MA. 2004. Microscopy Techniques Applied to the Study of Phytoplasma Diseases: Traditional and Innovative Methods. Current Issues on Multidisciplinary Microscopy Research and Education pp. 72-79.

in the sieve tubes, and, contrary to mycoplasmas, they possessed a clearly visible cell wall of the Gram-negative type (Bové 2006a), composed of a membrane and peptidoglycan layer (Garnier & Bové 1977). The HLB pathogens are surrounded by two triple-layered membranes: the inner cytoplasmic membrane and the outer membrane, as part of the Gram-negative cell wall (Moll & Martin 1974, Garnier & Bové 1977).

DNA Hybridisation and PCR

It has been difficult to consistently detect the liberibacters through any of the above methods, presumably because of the low concentration and uneven distribution of the pathogens in host plants and vector insects (McClellan 1970, Su & Chang 1974).

With the advent of DNA hybridisation and PCR, pathogens could be detected, and 'strains' distinguished (Jagoueix et al. 1997): see earlier information on strains in taxonomy section. 'In 1981, the HLB bacteria could be transmitted from citrus to periwinkle plants (*Catharanthus roseus*) by dodder (*Cuscuta campestris*). Total DNA from infected periwinkle plants served to clone genomic DNA fragments of '*Ca. L. asiaticus*' (a strain from Poona, India). One of the cloned HLB-DNA fragments, named In-2.6, was part of the bacterial β -operon (*rpl* genes for ribosomal proteins and genes for $\beta + \beta'$ subunits of RNA polymerase). In-2.6 was used to obtain, from '*Ca. L. africanus*' (a strain from Nelspruit, South Africa), a similar β -operon fragment, named As-1.7. Used as DNA probes, In-2.6 and As-1.7 were able to specifically detect the '*Ca. L. asiaticus*' and '*Ca. L. africanus*', respectively (Villeanoux et al. 1992, Planet et al. 1995). Dot-blot hybridisation was thus the first molecular technique used to detect the HLB bacteria in citrus. Finally, In-2.6 and As-1.7 (Hocquellet et al. 1999) used to define a pair of PCR primers, *rpl* A2 and *rpl* J5, which yield a 667bp amplicon with '*Ca. L. africanus*', and a 701bp amplicon with the '*Ca. L. asiaticus*' (Bové 2005). An additional primer set specific to '*Ca. L. asiaticus*' was developed, based on partial sequence of the h-operon (Hung et al. 1999a,b, 2004).

Because '*Ca. Liberibacter*' have not been cultured⁷⁰, only a few fragments of their genomic DNA have been cloned and sequenced (Jagoueix et al. 1994, 1997, Hung et al. 1999a,b, Subandiyah et al. 2000a, Villeanoux et al. 1993, Coletta-Filho et al. 2005, Teixeira et al. 2005c). The best characterised regions are the 16S rDNA and the 16S/23S intergenic regions (Jagoueix et al. 1994, 1997, Subandiyah et al. 2000a, Coletta-Filho et al. 2005, Teixeira et al. 2005c). The sequences of the 16S rDNA are highly conserved among the species of '*Ca. Liberibacter* spp.', but variation is sufficient to design primers capable of detection and identification of the bacterium in conventional PCR assays (Jagoueix et al. 1996, Coletta-Filho et al. 2005, Teixeira et al. 2005c).

'Molecular characterisation of the Asiatic and African HLB bacteria was reported in 1994 and 1997 (Jagoueix et al. 1994, 1997). The gene coding for 16S ribosomal RNA (16S rDNA) was obtained by PCR amplification with universal primers fD1/rP1, and sequenced. The HLB 16S rDNA sequences were used for the phylogenetic and taxonomical characterizations. The HLB bacteria were found to represent a new bacterial genus within the Gram negative α -Proteobacteria: the genus '*Candidatus Liberibacter*' ('*Ca. L.*'), with two forms: '*Ca. L. asiaticus*' for the Asiatic HLB form, and '*Ca. L. africanus*' for the African form. Forward primers Oln1 + 0Af1, and reverse primer Oln2c were designed from the HLB 16S rDNA sequences. With both '*Ca. L. asiaticus*' and '*Ca. L. africanus*', the same 1160bp amplicons are obtained. However, the amplicon from '*Ca. L. asiaticus*' has one *Xba* 1 restriction site and yields two fragments upon digestion, while '*Ca. L. africanus*' has two such sites and yields three fragments, making liberibacter identification straight forward. With either one of the two primer pairs, *rpl* A2 / *rpl* J5 or [Oln1 + 0Af1] / Oln2c, '*Ca. L. asiaticus*' and '*Ca. L. africanus*' can be detected most reliably in leaves showing HLB blotchy mottle, but not in symptomless leaves.

⁷⁰ There are two recent reports indicating that the bacteria can be cultured, but these reports (Davis et al. 2008, Schuenze et al. 2008) need to be confirmed by Koch's postulates. Davis et al. (2008b) attempted to isolate '*Ca. L. asiaticus*' using media formulations developed in response to the growth of another bacterium (from babaco) that appears to be related to the liberibacters based on 16S rRNA gene identities (93% relatedness to '*Ca. L. americanus*'). Cultures were obtained that were PCR positive for '*Ca. L. asiaticus*'. However, transmission electron microscope examination of the culture, PCR using generic primers, and sequencing of the PCR products revealed the presence of other bacteria in the cultures. These were actinobacteria related to *Propionibacterium acnes* based on 16S rRNA identities. The cocultures remained after attempts to purify the cultures by single colony isolation suggesting that the bacteria might be mutually beneficial to each other in culture. The cocultures survived more than 10 weekly passages to fresh medium. PCR using *P. acnes* specific primers indicated that actinobacteria are common inhabitants of citrus and psyllids, whether or not '*Ca. L. asiaticus*' is present.

These PCR methods make it possible to confirm HLB in suspicious trees, but they should not be used for indexing purposes.' (Bové 2005).

Primers f-GB1 and r-GB3 were developed from the 16S rDNA sequence of the new form '*Ca. L. americanus*' (Teixeira et al. 2005a,b,c). These primers are specific for '*Ca. L. americanus*', as they do not detect '*Ca. L. asiaticus*' and '*Ca. L. africanus*'. A duplex PCR method, with primers GB1/GB3 and *rplA2/rplJ5* for the simultaneous detection of '*Ca. L. americanus*' and '*Ca. L. asiaticus*' in the same PCR tube, has been developed and used routinely (Bové 2005).

Recently, loop-mediated isothermal amplification (LAMP) was developed for '*Ca. L. asiaticus*' detection in laboratories that lack thermocyclers (Okuda et al. 2005). Although conventional PCR and LAMP methods are sensitive and specific, consistent detection of HLB pathogens in infected plants or vectors has remained problematic (Halbert & Manjunath 2004, Okuda et al. 2005). Li et al. (2005) developed quantitative TaqMan PCR using 16S rDNA-based TaqMan primer–probe sets specific to the different '*Ca. Liberibacter*' forms. An additional primer–probe set based on plant cytochrome oxidase (COX) was used as a positive internal control to assess the quality of the DNA extracts. The assays do not cross-react with other pathogens or endophytes commonly resident in citrus plants, and are very sensitive. HLB pathogen DNA was successfully amplified from the equivalent of 20 ng of midrib tissue from symptomatic leaves. Initial results by Irey (2006a,b) using the real time PCR method of Li et al. (2005), indicated that the incidence of infection in Southern Florida based on PCR testing may be up to two times the incidence of infection estimated by visible symptoms alone.

At the Southern Gardens Laboratory of US Sugar, where 1600 samples have been run per week for HLB, Irey et al. (2008) used the following protocols: Real Time PCR Taqman, 16S Li primers, SDS/K acetate extractions for petioles, bark (best for budwood), and fruit peduncles. Receiver operating characteristic (ROC) curve analysis (see Turechek et al. 2008⁷¹) was used to provide guidance on threshold selection.

Li et al. (2007) compared and validated four PCR-based protocols, one-loop mediated isothermal amplification (LAMP) protocol and three Taqman real-time PCR protocols. The detection sensitivity of the validated conventional PCR assays are improved compared to the original protocols. All methods were reliable for confirmatory tests for the presence of liberibacters in symptomatic samples. There were no differences in assay specificity among the standard format PCR-based methods evaluated. The TaqMan real-time PCR was 10 to 100-fold more sensitive than conventional PCR and LAMP.

Several different PCR procedures have been tested at 13 laboratories in Florida (Irey et al. 2008): conventional and real time, different types of real time PCR (Taqman[®], SYBR Green[®] and EvaGreen[®]), multiplex vs. single primer sets for PCR, different master mixes, different primer sets, different machines and different systems for determining cycling threshold values. With the exception of laboratories that had specific reagent or equipment problems, all of the laboratories correctly identified the HLB status of > 93% of the samples. However, most of the labs missed one or more of the positive samples and several of the labs had what were considered false positive results (i.e., positive results from the known negative samples). Between labs using real time PCR systems and the same primers, no differences were observed between machines, reagents or detection systems. Similar detection sensitivity was found for tests using primers based on different genome regions, e.g., 16S rDNA, β -operon, or DNA polymerase nucleic acid sequences. Also no differences in results were seen between labs using multiplex vs. single primer sets for PCR. As

⁷¹ Turechek WW, Hartung JS, McCallister J. 2008. Development and ptimization of a real-time detection assay for *Xanthomonas fragariae* in strawberry crown tissue with receiver operating characteristic curve analysis. *Phytopathology* 98 (3): 359-368.

expected, conventional PCR was slightly less sensitive than real time PCR. **One point made was that you need a lot of samples to validate PCR reactions.**

The standard 'Bové' primers (Primers OI1 and OI2c [r16s primers, Jagoueix et al. 1996]) are not the preferred choice of Mike Irey (US Sugar Corporation, Florida) for a standard detection method. They are much less sensitive and more problematic than the primers designed by Hung et al. (2000) ('*Ca. L. asiaticus*' only) and the real time primers/protocol reported by Li et al. (2005) (Mike Irey, US Sugar Corporation, pers. comm., to California HLB Task Force 2007). These latter methods detected '*Ca. L. asiaticus*' in asymptomatic trees. At least one Brazilian group has designed real time primers (RT-PCR) in the same basic region as the Li et al. (2005) primers and they report approximately a 1000 to 2000 fold increase in sensitivity compared to the 'Jagoueix' primers. The 'Li' and Brazilian primers differ in the approach that they use, but they are to the same region in the 16S. The 'Li' assay is based on 3 different forward primers, one TaqMan probe, and one reverse primer to differentiate the species whereas, in the Brazilian approach, only one forward and reverse primer are used in conjunction with three different TaqMan probes to differentiate the species (Mike Irey, pers. comm., 2007, to the California HLB Task Force). Irey suggested, for initial confirmation of a diagnosis, doing a real time and a duplex conventional PCR using 'Jagoueix' and 'americanus' primers.

Irey et al. (2006b) asserted that if the wrong method was used to sample from a less than optimal tissue type during a less than optimum time of year, it is possible or even probable, that the presence of '*Ca. Liberibacter*' would not be confirmed and the sample would be a false negative.

Urasaki et al. (2008) reported '*Ca. L. asiaticus*' detection by Cycleave ICAN. The cycling probe enables the reaction to be done in one tube and to provide rapid results without electrophoresis.

Kawano et al. (2008a, b) developed a detection system that comprises the amplification of 16S rDNA by isothermal and chimeric primer-initiated amplification of nucleic acids (ICAN) and the detection of the amplified products with cycling probe technology. ICAN, which only requires two DNA–RNA chimeric primers, can be carried out using the 16S rDNA sequence. The cycling probe is a chimeric DNA–RNA probe that hybridises to an amplified target sequence, not to a nonspecific product, primer dimers. Once the probe hybridises, the RNA part of the probe is cleaved by Tli RNaseH. Thus the fluorescer ROX and quencher Eclipse on each side of the probe are separated, and red fluorescence is emitted. With this cycling probe technology, they (Kawano et al. 2008a, b) rapidly obtained red fluorescence from '*Ca. L. asiaticus*'-positive samples, and prevented the occurrence of false-positives. The performance of Cycleave ICAN and the conventional PCR system (Urasaki et al. 2008a) were compared using the 16S rDNA primers designed by Jagoueix et al. (1996). The sensitivity of the Cycleave ICAN was considered to be at least 25 times higher than that of the PCR–agarose gel system. The cycling probe enables the reaction to be done in one tube and to provide rapid results without electrophoresis. Compared with the PCR system, the Cycleave ICAN could shorten the time for the detection of '*Ca. L. asiaticus*' e.g., 4000 samples processed per person per year.

To improve the current detection limit of HLB-associated '*Ca. Liberibacter*' spp., Lin et al. (2008) developed a novel ultra-sensitive dual-primer TaqMan PCR for HLB molecular diagnosis. This new detection method significantly improves the sensitivity of detection of HLB-associated '*Ca. L. asiaticus*'. This system uses two sets of primers, analogous to the standard nested PCR and two sequential amplification steps. However, unlike two-tube nested PCR, this dual-primer Taq-Man PCR is carried out in a single closed tube. Computational algorithms were used to carefully design set of primers and probes that had the least interactions and avoid any possible self and cross dimer formations. PCR conditions were optimised such that each pair of primers worked sequentially during the amplification process. Specificity of the designed primers was validated by *in silico*

BLAST and PCR tests with other citrus disease pathogens, and citrus and insect vector DNAs. The specificity of this detection system is high because the target amplicon was amplified sequentially by specific dual primers and the fluorescent signal is detected only from the probe which specifically hybridizes with the target amplicon. The sensitivity of this dual primer detection system is significantly higher than that of a standard Taq-Man PCR and has comparable sensitivity to a two-tube nested PCR. However, the standard two-tube nested PCR procedure requires a second amplification from the first amplified product in a separate tube. This processing of the previously amplified products could cause the cross contamination and lead to false positives, making this approach risky for practical application unless extreme caution is taken. Also, the cost of consumable reagents is reduced by nearly half with this new single-tube dual primer Taq-Man PCR protocol compared to the conventional two-tube nested PCR. Like other real-time PCR, this new system is gel-free and results are available immediately after the PCR is completed. Therefore, it is particularly suitable for high through-put processing of large numbers of clinical samples. In a recent survey from HLB infected citrus groves, the comparative detection rate was ~12% higher using the single-tube dual primer Taq-Man PCR protocol than that using the single primer pair real-time PCR method. Cloning and re-sequencing of the amplicons confirmed the detections were true positives. Availability of a simple, ultrasensitive detection system will be an extremely useful tool for detecting and monitoring the spread of HLB-associated '*Ca. Liberibacter*', and for early diagnosis of HLB.

Benyon et al. (2008) noted that nested PCR, coupled with improved sampling and bacterial DNA isolation methods (Zhou et al. 2008c), are essential in order to detect '*Ca. L. asiaticus*' in certain phenotypes of HLB, or from psyllids that carry a low titre of the bacterium. Zhou et al. (2008c) increased detection of the '*Ca. L. asiaticus*' bacterium in seedlings grown from '*Ca. L. asiaticus*' positive seeds over real time PCR detection, 14% and 20%, from citrus and periwinkle, respectively.

Detection of '*Ca. Liberibacter*' in Psyllids

Preservation of psyllids for collection and extraction is another important component of effective diagnostics. It was noted, that for psyllids properly stored in ethanol at -20°C for 18 months, there is no noticeable change in detectability of HLB pathogens. However, psyllids collected from sticky traps lose bacterial titre over time and the pathogens could not be detected after 7 d. Therefore, if used, survey traps need to be checked at very close intervals (every 1 to 3 d)⁷².

Bové et al. (1993) cloned a DNA fragment (In 2.6) from a Poona (India) strain of the HLB organism and used it as a probe for the detection of '*Ca. L. asiaticus*' in single Asiatic citrus psyllids collected in India and Malaysia.

Hung et al. (2004) developed a PCR-based assay for monitoring '*Ca. L. asiaticus*' in vector psyllids using a rapid DNA extraction from psyllid bodies and PCR amplification. The entire procedure for '*Ca. L. asiaticus*' detection in psyllids can be completed within 5 h. Using this method, '*Ca. L. asiaticus*' can be accurately detected in psyllid adults, as well as nymphs, in different instar stages. The assay is sensitive enough for '*Ca. L. asiaticus*' detection in single-psyllid extracts from adult, fifth, fourth and third instars.

Manjunath et al. (2008a) adapted the TaqMan based real-time quantitative polymerase chain reaction methodology of Li et al. (2006) for detection of '*Ca. L. asiaticus*' in *D. citri* in Florida. Psyllids positive for '*Ca. L. asiaticus*' were found prior to finding HLB positive plants in surveys.

⁷² http://www.aphis.usda.gov/plant_health/plant_pest_info/citrus_greening/downloads/pdf_files/twg-final2007.pdf

Thus a positive result from a psyllid analysis may be informative and useful for undertaking appropriate management decisions, but negative results may not indicate absence of HLB in an area. A nymph sample with '*Ca. L. asiaticus*' would indicate that the source plant is infected, while an adult with '*Ca. L. asiaticus*' may indicate only the presence of infected trees in the vicinity.

In related studies in Brazil, Manjunath et al. (2008b) found that liberibacters can be identified in *D. citri* 'long before symptoms become visible in plants' and that this demonstrated 'the usefulness of psyllid analysis in monitoring different management practices'.

The '*Ca. L. asiaticus*' incidence among *D. citri* populations collected on HLB-affected citrus plants in the field in Florida varied from 10% to 100% (Li et al. 2008). The bacterial populations complied with a normal distribution with some skewness among the psyllid populations. One quarter of the *D. citri* populations carried '*Ca. L. asiaticus*' populations of less than 104 '*Ca. L. asiaticus*' cells/psyllid, which was on the borderline of the low detection limit of real-time PCR, but beyond the detection range of conventional PCR. About 3% of the infected psyllid populations retained '*Ca. L. asiaticus*' populations up to 108 '*Ca. L. asiaticus*' cells/psyllid, which had an elevated ratio of up to 1:1 of '*Ca. L. asiaticus*' DNA to DNA in copy number. This ratio was approximately 1500 fold higher than that of '*Ca. L. asiaticus*' DNA to plant DNA obtained from symptomatic tissues of HLB affected citrus plants collected in the field in Florida.

Bové (2006a) reported detection of '*Ca. L. asiaticus*' and '*Ca. L. americanus*' in *D. citri* in Brazil.

Degree of Testing in Areas where HLB is Endemic

In Florida, there are two state-run diagnostic laboratories screening for HLB: at the Southwest Florida Research and Education Center in Immokalee (which processed 8157 samples in 2 months) and at Gainesville, and a private laboratory in Clewiston (Southern Gardens Diagnostic Laboratory, SGDL) run by US Sugar Corporation. For the 12 months, 1 July 2007 to 30 June 2008, SGDL ran 35,006 samples from 1125 orchards for an average of 2917 samples a month: see www.imok.ufl.edu/hlb.

Sampling Methodologies for PCR

Seasonality developmental stages of the host(s) and climatic conditions

A phytotron experiment and field observations showed that '*Ca. L. africanus*' is heat-sensitive, and occurs only in cool areas, with temperatures remaining below 30°C to 32°C. On the contrary, HLB in Asia caused by '*Ca. L. asiaticus*' is heat tolerant, and symptoms occur even when temperatures are well above 30°C (Bové et al. 1974, Bové 2006a). Bové (2006a), citing (Teixeira et al. 2005c) stated, that in the glasshouse, sweet orange seedlings, graft-inoculated with '*Ca. L. americanus*', showed severe HLB leaf mottle at both cool (22°C to 24°C) and warm (27°C to 32°C) conditions. He suggested that these observations indicated that '*Ca. L. americanus*' is heat-tolerant like '*Ca. L. asiaticus*' (Bové 2006a). However, heat sensitivity was not mentioned by (Teixeira et al. 2005c) and Lopes et al. (2008) state that '*Ca. L. americanus*' is less heat tolerant than '*Ca. L. asiaticus*'. Lopes et al. (2008a,b) stated that when affected trees were maintained for 60 days at daily cycles of 27°C to 32°C, or for 90 d at 24°C to 35°C, a complete symptom remission in the new vegetative flushes was observed in '*Ca. L. americanus*'-, but not in '*Ca. L. asiaticus*'-affected trees. Contrary to the '*Ca. L. asiaticus*'-affected trees, the pathogen was not detected in any tree previously affected by '*Ca. L. americanus*'. '*Ca. L. asiaticus*' was however affected by the 24°C to 38°C daily cycle, a temperature condition totally detrimental to '*Ca. L. americanus*'. Liberibacter thermal sensitivity

might explain the irregular spatial progress of HLB in São Paulo, which has moved to a lesser extent towards the north and northwest regions of São Paulo.

HLB symptoms appear throughout the year in Brazil, but with greater intensity in autumn and winter (April to August), because in addition to mottled leaves, affected shoots also show leaves with Zn/Mn like deficiency patterns (Lopes et al. 2006a).

In Florida, where HLB is caused by the heat-tolerant form, '*Ca. L. asiaticus*', sampling is best from early autumn to early spring. Mature trees in Florida typically produce major flushes of growth during early spring and summer and sometimes minor flushes of growth during late summer and fall. These flushing periods are usually synchronised with all trees across a block producing flush at the same time. There may be little or no production of new leaves between these major and minor flushing periods. Young citrus trees also exhibit flushes of new growth each year generally at the same times as older trees, but periods of flush growth by young trees may be less synchronised than older trees. Young trees often appear to flush almost continually during favourable weather conditions (Hall & Albrigo 2007). In Florida, it is recommended to avoid collecting samples during leaf flushes – stop when feather flushes are approx 4-6 cm long and resume when leaves from the recent flush are fully expanded and beginning to harden off (Sampling Protocol, Southern Gardens HLB Diagnostic Laboratory: see below).

In China, Zou Gen (South China Agricultural University, pers. comm., 2007) found that titre of '*Ca. L. asiaticus*', determined by nested PCR, was correlated roughly with monthly temperature.

'*Ca. L. africanus*' is inactivated by lower temperature×time impacts (Schwarz & Green 1972). Severe symptoms caused by '*Ca. L. africanus*' are obtained under cool glasshouse conditions (22°C for 8 h nights and 24°C for 16 h days), whereas no symptoms occur at temperatures ranging from 27°C to 30°C. Presumably titres of '*Ca. L. africanus*' are higher at the lower temperatures.

Given that monthly average temperatures vary across citrus growing areas in Australia from the tropical north to the temperate conditions in southern Australia and that flushing times may vary dependent on rainfall, as well as temperature (Broadbent 1992), it is conceivable that the optimum sampling time for detecting '*Ca. L. asiaticus*' will vary with region (Table 4).

Table 4. Timing of growth flushes in the major citrus growing regions of Australia (Broadbent 1992).

Region	Source of information	Timing of growth flush
Gayndah, Central Burnett (Qld.)	John Owen-Turner	80% leaf flush:mid-November
Kulnura, Central Coast (NSW)	Ruhi Sarooshi	80% leaf flush:mid-November Major flush in autumn
Sunraysia	Ken Bevington, Robert Emmett	Spring flush commences in early August; shoot elongation complete by end of September but leaf expansion continues through October and is 80% complete by early to mid October. The second growth flush in early December and third growth flush in early February are less regular and general than spring flush.
Griffith (Riverina)	Lou Revelant	80% leaf expansion in mid-late November

Hutton (2004) made the following observations: 'vegetative growth on Valencia orange trees grown on *P trifoliata* rootstock at Yanco (NSW) was evident from late August to mid May. Peak periods of activity occurred during spring, in association with flowering, and during late summer. Timing of growth flushes varied from year to year. The cold late winter and early spring temperatures experienced in the MIA delayed the initiation of spring growth flush

until mid to late August. However completion of shoot extension growth and full leaf expansion were concentrated over a short duration and by early December, trees were at a similar stage of phenological development to those growing in other warmer inland irrigated regions of southern Australia. Shoot extension growth (non-flowering shoots) continued until late-November, with full leaf expansion being attained about 3 weeks later in mid-December. The spring growth flush was characterised by a high proportion of vegetative shoots and consequently this flush made a major contribution to annual vegetative growth. In addition, approximately 70% of flowering shoots were of the leafy inflorescence type in both years. Compared to the dominant spring growth flush, minor annual variation was evident in the amount of vegetative growth that occurred during summer and autumn. At this time, sporadic shoot growth was only evident on a small proportion of the vegetative shoots developed in the previous season. The summer and autumn growth flushes accounted for only 30% and 5% respectively of the total annual shoot growth produced in both the “off” crop and “on” crop years.’

Tissue type

Asymmetric blotchy leaves should be used for sampling for PCR. However, Duan et al. (2008a) reported what they considered to be a unique disease phenotype – yellow shoot without blotchy mottling of leaves - with the yellow shoots (and psyllids collected from them) containing a very low titre of ‘*Ca. L. asiaticus*’ often not detected by conventional and real-time PCR protocols, making the use of nested PCR (see Benyon et al. 2008) essential.

Li et al. (2009) found that the populations of ‘*Ca. L. asiaticus*’ inferred from the distribution of 16S rDNA sequences specific for ‘*Ca. L. asiaticus*’ in leaf midribs, leaf blades, and bark samples varied by a factor of 1000 among samples prepared from the six citrus species tested and by a factor of 100 between two sweet orange trees tested. In naturally infected trees, above-ground portions of the tree averaged 10^{10} ‘*Ca. L. asiaticus*’ genomes/g of tissue. Similar levels of ‘*Ca. L. asiaticus*’ genomes were observed in some, but not all, root samples from the same plants. In samples taken from greenhouse-inoculated trees, levels of ‘*Ca. L. asiaticus*’ genomes varied systematically from 10^4 genomes/g at the graft inoculation site to 10^{10} genomes/g in some leaf petioles. Root samples from these trees also contained ‘*Ca. L. asiaticus*’ at 10^7 genomes/g. In symptomatic fruit tissues, ‘*Ca. L. asiaticus*’ genomes were also readily detected and quantified. The highest levels of ‘*Ca. L. asiaticus*’ in fruit tissues were found in the locular membranes and septa (10^8 genomes/g), with 100-fold lower levels of ‘*Ca. L. asiaticus*’ in the meso and pericarp of such fruit.



Figure 48. Asymmetric blotchy mottle, the diagnostic symptom for sampling for PCR confirmation in Brazil (Pat Barkley).

Collecting samples of suspect material

Particular care must be given, when collecting individual specimens, to prevent contamination of samples and to maintain confidence in the sample results. Collectors must exercise extreme care in handling specimens to ensure that hands, tools, and other collection supplies do not become a

source of contamination between samples and particularly between individual sites. Other exotic pests and pathogens may be present. Most countries with 'Ca. L. spp.' also have citrus canker.

Wash bottles containing soap and disinfectant must be provided to disinfect hands and small articles. Special care must be taken with pruning instruments and other items used for sampling. Care must also be taken with larger articles such as shoes, clothing and vehicles, to be certain that these do not become a means for contamination, or spreading pathogens (e.g., citrus canker) if present. See QDPI&F Work Instruction ST-W-006⁷³.

Data collection

During surveys, data, especially at the site of detection or occurrence, must be recorded according to guidelines set out in ISPM 9 (1998) Guidelines for Pest Eradication Programmes. Data collected during a preliminary investigation should be used to estimate the potential for spread and the anticipated rate of spread, and to identify endangered areas. Information gathered and recorded on the Survey Form should include:

- geographical location using GPS; see QDPI&F Work Instruction ST-W-001;⁷⁴
- hosts infested at the site including age, variety/clone, rootstock, phenology;
- extent and impact of damage and level of pest prevalence;
- how the pest was detected and identified;
- recent imports of plants or plant products including nursery stock movements;
- history of the pest on the property or in the area;
- movement of people, products, equipment, conveyances;
- mechanism of spread within the area including likely source of inoculum (infected trees, infected budwood, spread by storm etc.);
- climatic events and soil conditions including storms and prevailing wind directions;
- condition of infested plants including age of plant parts affected (spring flush/autumn flush etc); and
- orchard management including method of irrigation, cover crops and spray programs.

Sampling protocol

Sample collection procedures used in Florida are outlined in Gomez (2008). Each sample collected should contain green twigs of 15 cm to 20 cm long with approximately 20 leaves, preferably with the petiole still attached and with good recognisable symptoms. Measures should be taken to avoid the presence of the insect vector in the sample bag. Sample should contain leaves showing blotchy mottling (Carlos et al. 2006).

The total number of HLB symptomatic plants must be recorded. Samples should, if possible, be photographed before they are removed from plants. The entire plant should also be photographed and include the affected area of plant. Other photographs should include a perspective of where the symptomatic plant is located with respect to other plants. A minimum of 3 photographs per symptomatic plant is recommended, unless several plants in a block are symptomatic, in which case fewer photographs may be need to be taken.

⁷³ Telford G. 2007 Decontamination and Hygiene Requirements When Conducting a Survey for Citrus Canker. QDPI&F Work Instruction ST-W-006.

⁷⁴ Telford G. 2007. Global Position System (GPS) Unit Use and Calibration. QDPI&F Work Instruction ST-W-001.

Collection of samples from symptomatic field trees

The procedures used in Brazil are: trees with HLB-like symptoms are labelled along with the first and last trees of the row to indicate presence of a suspect tree within that row, for sample collection and ultimately tree eradication. After sample collection, a second label is attached to the suspect tree. If the laboratory result is negative, the seal is removed. In the case of a positive laboratory result, a third marking is made in paint on the trunk, indicating the tree is to be eradicated (Massari & Libanori 2006).

The sampling protocol for the Florida Southern Gardens HLB Diagnostic Laboratory (http://www.flcitrusmutual.com/content/docs/issues/canker/sg_samplingform.pdf) specifies:

1. Samples should be collected from the symptomatic areas/branches of the trees.
2. Samples should consist of short sections (4-6 inches or greater) of symptomatic branches with the attached leaves. If fruit are present on the branches, the fruit can either be left on or they can be trimmed off. If the fruit are trimmed off, the peduncle should be left on the sample (i.e., trim the fruit off as close to the button as possible leaving the peduncle on the branch).
3. If a variety of symptoms are present, the preferred samples (in order of preference) would be:
 - a. branches with mottled leaves;
 - b. branches that contain shoots that are almost entirely yellow;
 - c. branches that have leaves with yellow veins;
 - d. branches with leaves that have either green islands on a yellow background or yellow islands on a green background;
 - e. branches with nutrient deficiencies that have a ‘rabbit’s ear’ appearance (small, upright leaves);
 - f. branches with leaves that show chlorosis and ‘vein-corking’;
 - g. branches with Zn and/or Fe deficiencies that are not related to blight or other known causes.
4. Place the leaves/twigs into a sealable (e.g., zip-lock) plastic bag and keep the sample cool and out of the sunlight.

Sample handling and shipping

1. Each sample should be in an individual sealable plastic bag (zip-lock).
2. A completed sample submission form should be included in the bag (or stapled) with each sample.
3. Samples should be double bagged.
When multiple samples are being submitted, multiple samples can be placed in one or more larger sealable bags, however each individual sample needs to be bagged individually and have its own individual completed sample submission form attached.
4. Samples should be kept cool and out of direct sunlight until shipping (i.e. esky with ice, esky or box w/o ice kept in the shade, etc.).
5. If at all possible, the samples should be shipped or hand delivered the same day that they are collected. Samples must be kept cool (but not frozen).
6. Samples should be shipped by overnight mail or courier and must not be shipped or held over the weekend.
7. Samples to be shipped to an interstate laboratory may require a permit.

Surveyors should forward specimens, complying with the recommended sampling and handling procedures and provide a completed Survey Form including details on the address, owner, GPS co-ordinates, varieties affected, disease symptoms and site features. For guidance, see QDPI&F Work

Instruction ST-W-007⁷⁵; QDPI&F Work Instruction ST-W-008⁷⁶; and QDPI&F Work Instruction ST-W-011⁷⁷.

Samples from remote sites

Davis et al. (2005) used the following method for collecting and preserving plant samples from Papua New Guinea (PNG) for later analysis using PCR techniques to determine the HLB status of a suspect plant. Citrus trees were targeted from which approximately 12 young leaves per tree (Weinert et al. 2004) that exhibited green on yellow vein banding, general chlorosis, chlorotic mottling, corking of leaf veins or short upright and bushy growth habit were collected. Approximately 1 g of petioles and midribs excised from leaves that had been surface sterilised in a solution of 1% available chlorine were chopped finely, desiccated over anhydrous calcium chloride, then frozen.

Submission form

We suggest the following format for a submission form for insect and plant tissue samples:

Insect and Plant Tissue Sample Submission Form for HLB and its Vectors				
Collector:		Date of collection:		
Collection number:		● Photograph numbers:		
State:	Region:	Nearest town:		
Name and address of farmer (if applicable):				
Latitude:	Longitude:	Altitude:		
Vernacular / cultivar name:				
Status: Orchard	Nursery	Backyard	Wild	Other (specify)
Size of planting:				
Surrounding vegetation:				
Description of symptoms:				
<i>Diaphorina citri</i> :	Present / Absent	Common / Rare		
<i>Trioza erytrae</i> :	Present / Absent	Common / Rare		
HLB symptoms:	Present / Absent			
Date received:	Laboratory / number:			
Identified by:	Date:			
Name of institution:	Accession number:			

⁷⁵ Telford G. 2007. Collecting a Sample from a Plant that is Suspected of being Infected with Citrus Canker. QDPI&F Work Instruction ST-W-007.

⁷⁶ Telford G. 2007. Packing and Dispatch of Samples for Diagnostic Analysis. QDPI&F Work Instruction ST-W-008.

⁷⁷ Telford G, Benham M, Jarrett K. 2007. Completion of Form ST-F-001 (Citrus Canker Survey Form – Orchard). QDPI&F Work Instruction ST-W-011.

Assigned laboratories

Samples should be sent to an approved laboratory in the affected State/Territory and to the designated diagnostic laboratory'

Transportation and laboratory facilities must be organised so that samples are processed within 24 h to 48 h of collection.

A number of support laboratories are also required to provide confirmation of diagnostic tests from the assigned laboratory, when there is an excess of material to be tested, when specific techniques and expertise is required or when skilled personnel at the assigned laboratory are not available.

Criteria for the determination of a positive or negative result

The following criteria are used by the Florida Southern Gardens HLB Diagnostic Laboratory (http://www.flcitrusmutual.com/content/docs/issues/canker/sg_samplingform.pdf):

Test results fall in one of three categories:

- HLB positive – test results indicate that '*Ca. Liberibacter* sp.' was detected in the sample;
- no HLB found – test results did not indicate that '*Ca. Liberibacter*' was present in the sample; or
- an inconclusive test result (re-testing should be done).

No testing procedure is 100% accurate. If a sample is designated as 'no HLB found', this does not mean that the tree/plant from which the sample was taken is disease-free – it means that no '*Ca. Liberibacter*' was detected in the sample. This could be because:

- no '*Ca. Liberibacter*' was present;
- '*Ca. Liberibacter*' was present, but below the limit of detection;
- '*Ca. Liberibacter*' was present, but the sample was inadequate for testing (sample was in poor condition, wrong tissue type was sampled, wrong sampling time); or
- the test failed.

In Australia, similar symptoms to those of HLB are caused by Australian citrus dieback (Broadbent et al. 1976, Broadbent 2000) and sometimes by severe stem pitting strains of CTV in grapefruit. A phytoplasma has been associated with Australian citrus dieback (Davis et al. 1997, Monique Garnier, pers. comm., 1998). It is recommended that a phytoplasma probe be used on all negative suspect samples.

Notification of symptoms

If a grower, consultant, or other person detects a suspect case of HLB, *D. citri* or *T. erytrae*, this person should ring the Exotic Plant Pest Hotline **1800 084 881** which will notify a representative of the Plant Health Manager of the State or Territory in which the samples were found.

If a diagnostic laboratory receives samples of diseased material suspected of being HLB or citrus psyllids, notification to the Plant Health Manager of the State or Territory in which the samples were found should include a full description of the symptoms or pest and the reasons why these are suspected to be those of HLB or a citrus psyllid.

The States' Plant Health Manager will immediately conduct a preliminary investigation of the incident. If reasonably certain that the suspect disease is HLB or psyllid either *D. citri* or *T. erytreae*, the State Plant Health Manager should notify the Chief Plant Protection Officer, Australian Government Department of Agriculture, Fisheries & Forestry, providing a brief report on the detection. The manager of plant health should also notify the owner or manager of the area in which the suspected samples were found as well as the person who reported the incident.

The CPPO will notify PHC and IPHRWG members, BA/ AQIS, PHA and the nominated representative of Citrus Australia Limited.

Sampling protocol for submission of suspect psyllid samples

If psyllids are forwarded for detection of the HLB pathogens, make sure the insects are first correctly identified as citrus psyllids. This is especially important in states or areas where the citrus psyllid is **not** known to occur.

After several citrus psyllids in an area have been confirmed, rely on local identifiers for verification of psyllid samples.

Psyllid samples taken for PCR analysis should be collected live and preserved in alcohol immediately. Psyllids that have been dead for more than two days (including those on sticky traps) will **not** yield accurate results when analyzed using PCR.

Identification of citrus psyllids carrying HLB requires two steps:

Step 1. Confirm that the insect is a citrus psyllid.

Step 2. Conduct PCR analysis of citrus psyllids to detect HLB.

- For psyllid identification, place the insects in a leak-proof vial containing 70% ethyl alcohol.
- For PCR analysis for '*Ca. Liberibacter*' (or phytoplasma), place the insects in a leak-proof vial containing 95% ethyl alcohol. The proper alcohol concentration is important for effective PCR analysis.
- Submit at least 3 insects; more are preferable.
- Write the sample ID number in pencil on a label inserted into the vial.
- Some overnight carriers will not accept specimens preserved in alcohol, due to regulations on air transport of flammable materials. Ground transportation may be required.

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THE EXOTIC PLANT PEST HOTLINE

The Exotic Plant Pest Hotline is a free call telephone service provided for members of Australia's plant production sectors and plant health services to report suspect detections of unusual plant pests, weeds and diseases. The hotline will be staffed during normal working days and business hours in all States and Territories. The service allows callers to directly report suspect pest detections to an area where action can be taken by knowledgeable staff.

When you call the Exotic Plant Pest Hotline, you will be transferred to a representative of the primary industry or agriculture department/agency in your State or Territory. Each agency will then have responsibility for reviewing information provided, and for taking any necessary follow up action. An operator from your state or territory will greet you and determine:

- The nature of the information you provide regarding your report of a suspect plant pest; and
- An appropriate course of action to be taken.

Exotic Plant Pest Hotline - 1800 084 881

SURVEILLANCE

General references

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http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=209681.

⁷⁸ http://www.aphis.usda.gov/import_export/plants/ppq_manuals.shtml.

Survey Precautions

Take the following precautions before starting a survey.

- **Pesticide Applications:** Before starting a survey, always determine if there have been recent pesticide applications that would make it unsafe to inspect the citrus.
- **Private Property:** Obtain permission from the landowner before entering a property.
- **Sanitation:** see page 90: Collecting samples of suspect material

Post- incursion Pre-endemic Specific Surveys

Specific surveys are procedures by which information is obtained on particular pests and diseases of concern on specific sites in an area over a defined period of time (ISPM 6).

In 1915, GF Hill collected *D. citri* at Stapleton in the Northern Territory while surveying for citrus canker (Bellis et al. 2005). Citrus canker was detected in an orchard of 95 citrus plants in this area in 1912 (Hill 1918). The source of the infection is believed to have been plants imported into the Darwin Botanic Gardens, probably from China or Japan, and it is possible that the infestation of *D. citri* arose from a similar importation. In 1918 all trees on affected properties were destroyed, mostly by burning (Hill 1918). In 1922, a decision was made to eradicate all citrus trees in NT north of latitude 19°S, about 700 km south of Darwin, and to prohibit the replanting of citrus trees until 1925 (Anonymous 1922, Mertin 1952). No records exist of subsequent collections of *D. citri* in the Northern Territory, nor have there been any reported cases of HLB. Surveys for exotic pests and diseases, including *D. citri* and HLB, which are regularly conducted in Darwin by the Northern Territory Department of Business, Industry and Resource Development (NTDBIRD), and throughout coastal Northern Territory by the Northern Australia Quarantine Strategy (NAQS) of the Australian Quarantine and Inspection Service (AQIS), have not thus far detected either organism (ESC Smith, NTDBIRD, pers. comm. 2003, GA Bellis, NAQS, unpubl. data, 2003, Weinert et al. 2004, Bellis et al. 2005).

Surveys over the past 10 years in Australia have failed to detect any psyllid species on Aurantioideae in Australia. Any psyllid found on a member of the Aurantioideae should be considered highly suspicious.

Most recently, CSIRO surveyed for Psyllidae and related insects on native and introduced species of Rutaceae in the tribes Aurantieae and Clauseneae in the subfamily Aurantioideae in northern Australia. No psyllid species, other than some hosted by plants in other families that were coincidentally present, were found on plants in this sub-family during the surveys (Paul De Barro, CSIRO Entomology, pers. comm., 2007: see Appendix XII).

HLB and *D. citri* are pests targeted by NAQS and NAQS scientists survey specifically for these both domestically, in the Torres Strait, Northern Australia and adjacent islands; and overseas, including PNG, Indonesia, and East Timor (Davis et al. 2000, 2005, Weinert et al. 2004, Grimshaw et al. 2006), where HLB and *D. citri* are endemic.

The onshore component of the program covers a coastal band of 20 km in width from Broome in the west to Cairns in the east. NAQS surveys encompass citrus species in backyards and orchards as well as native Rutaceae. The frequency of surveys depends on the classification of risk zones, with high-risk areas being surveyed twice each year.



Figure 49. NAQS survey areas in northern Australia (R Davis).

In recognition of the need for increased surveillance and diagnostic capacity in Queensland after the detection of HLB and *D. citri* in northern western PNG, QDPIF initiated an intensive surveillance program in 2006. QDPIF surveillance provides early warning of the presence of target organisms (including HLB and *D. citri*), where there are risk-pathways identified. It focuses on urban, peri-urban, remote areas and hazard sites, as well as orchards throughout Queensland. Trained Biosecurity Queensland inspectors and plant health scientists are involved in surveillance statewide. A variety of hosts are inspected including native *Citrus* and other species of Rutaceae. QDPIF also actively encourages public reporting of emergency plant pests, with all reports investigated and information captured (Ceri Pearce, QDPI&F, pers. comm., 2008).

The targeted surveys conducted by NAQS and QDPI&F serve as an early warning system for the detection of exotic pests and diseases, including HLB and its vectors, but only over a limited area. Surveillance for exotic diseases in Australia's citrus production areas occurs only irregularly and often on an informal basis. The citrus industry has a limited number of industry development officers working in the field, who provide extension services, but who do not specifically survey for exotic pests such as citrus canker and HLB. Industry-funded activities are directed predominantly to the management of established pests, but represent a pool of expertise that does, or has the potential to, provide early warning of new pest incursions and underpin claims of the absence of particular pests (Dempsey et al. 2004). State Government pathologists, more experienced in identifying exotic pathogens of citrus, occasionally visit economically important plantings and may keep an eye out for symptoms of exotic or unfamiliar looking diseases.

Post- incursion Pre-endemic Delimiting Surveys

Upon detection of *D. citri*, *T. erythrae* and /or HLB, delimiting surveys will be conducted by relevant State or Territory departments of agriculture or primary industry where the incursion is recorded. These delimiting surveys will determine the size of the pest quarantine area if eradication is feasible. A buffer zone or restricted area around affected sites should be established until the extent of the incursion has been determined. The extent of surveillance activities and the size of quarantine zones is the decision of the CCEPP or an associated technical panel and will vary depending on many factors including climate and prevailing weather, proximity to commercial groves and resource availability.

Delimiting surveys must be carried out on residential properties, commercial and abandoned orchards, nurseries (both retail and production), parks, retail outlets selling *Citrus* (commercial and native species and varieties), and species of *Murraya* (e.g., orange jasmine), *Bergera* (e.g., curry

leaf) and *Clausena* (e.g., huangpi or wampee), weekend markets and roadside stalls. If native citrus occurs in the area, these must also be inspected.

Responses will depend on where incursions are detected. Regions where commercial orchards and nurseries occur require the most rigorous delimiting surveys to determine the extent of an affected area, or areas. Information on delimiting surveys for HLB in Floyd & Krass (2006)⁷⁹, provides background guidelines for carrying out delimiting surveys in urban and commercial areas. However, these strategies are difficult to apply in Australia, where HLB is not endemic, citrus orchards are relatively small⁸⁰ and widely and irregularly dispersed in coastal environments, riparian zones and inland irrigation areas, sometimes with native *Citrus* species in close proximity and with *M. paniculata* present naturally or as a common garden ornamental.

The first point of detection may not be the initial location of the incursion. Trace-back and trace-forward analyses must therefore be undertaken to determine the source of an incursion and to identify other premises or locations that may have been exposed because of their proximity to the point of initial detection, movement of infected planting material or fruit, or prevailing winds carrying adult psyllids.

Delimiting surveys must be carried out by specifically trained personnel under the supervision of citrus pathologists and entomologists, experienced in HLB epidemiology and psyllid recognition, with botanists familiar with *Citrus* and *Citrus* relatives, and meteorological inputs.

Surveyors should be trained to ensure that they are capable of recognising HLB symptoms, stages in the life cycle of the psyllid vector, direct damage and honeydew associated with the vector and damage, and that they have sound knowledge of the biology of the pathogen and the vector. They must also be able to identify hosts of the pathogen and the vector, and to differentiate HLB symptoms from symptoms of other citrus diseases, and nutrient disorders (see Floyd & Krass 2006, Gomez 2008).

Details of the survey will be recorded on the Survey Form (for an example see Telford et al. 2007. Completion of Form ST-F-001 (Citrus Canker Survey Form – Orchard). QDPI&F Work Instruction ST-W-011) and any specimens (insect or plant) collected will be submitted with a completed Sample Specimen Report (see page 93).

The surveys must be completed as soon as possible. Any delay may be critical in restricting further spread.

The likely distribution of all known hosts (as listed in Appendix V) within a 5 km radius of the point of detections should be determined and mapped. Citrus Australia national planting statistics database for citrus, herbarium records for native *Citrus* species and *Citrus* relatives, town maps for the location of households and parks, and Google Earth should be used for this purpose.

⁷⁹ http://www.aphis.usda.gov/import_export/plants/ppq_manuals.shtml.

⁸⁰ From, A snapshot of Australia's citrus plantings. Australian Citrus News 85, p. 5 (2009).

TABLE 3. THE CITRUS INDUSTRY'S AVERAGE PROPERTY SIZE	
Property Size	%
< 10 ha	66
10 – 20 ha	17
20 – 40 ha	10
> 40 ha	7

If the incursion is detected within an orchard or nursery, all trees within the orchard or nursery should be inspected.

In all other circumstances, host plants, where they occur, should be surveyed for psyllid infestations and symptoms of HLB within a radius of 200 m of the initial point of detection.

After these initial inspections, the survey should resume, where hosts are distributed, at 200 m intervals on all (e.g., in the Riverina) or part (e.g., narrow coastal regions or orchards adjacent to rivers) of the circumference of a circle with a 5 km radius from the point of detection. If no psyllids or symptoms of HLB are found at these survey points, additional surveys should begin sequentially on the same basis at 1 km increments back, at 100 m intervals, towards the location of the initial detection. The potential number of survey points along each annulus is given in Table 5. At each survey point, surveyors should inspect hosts in the immediate area. They must record positive or negative observations.

Distributions of *D. citri*, and HLB when transmitted into initially HLB-free orchards, tend to be clumped around points of entry into orchards and then around subsequent points of dispersal, and influenced by movement of people and equipment within orchards, wind intensity and direction, and the proximity of adjacent plants (for hedgerows, spread tends to be greater within rows than between rows). Information suggests that the psyllid: is not a strong flyer and dispersal over considerable distance is wind assisted or occurs via the movement of infested plants; jumping/landing behaviour such as when disturbed is likely to be less 8 m; dispersal is prompted by high populations; may move at least several kilometres during normal air current assisted dispersal flights; may move far greater distances during high wind events. The psyllid nymphs are not active walkers and it is not expected that they contribute significantly to dispersal.

Halbert & Núñez (2004), based on records by Florida Department of Agriculture and Consumer Services, Division of Plant Industry inspectors, indicate that *D. citri* can move on shipments of fresh, unprocessed citrus fruit so this should also be considered as a potential pathway for *D. citri* and, as individual psyllids may be infective, also of HLB pathogens. *D. citri* has also been transported in empty fruit trucks in Parana State Brazil (J Graham, University of Florida, pers. comm., December 2008).

If hosts are distributed in a narrow coastal region, or along rivers, it is recommended that surveys also extend in 1 km increments outwards from the 5 km radius to 10 km.

Table 5. Number of survey points at approximately 200 m intervals on concentric annuli at 1 km intervals from an initial point of detection.

Radius of circle (km)	Number of survey points
1	30
2	60
3	90
4	120
5	150
6	180
7	210
8	240
9	270
10	300

If heavy, extensive infestations are found 4 to 5 km from the initial detection, a second delimiting survey should be undertaken as the first point of detection may not have been the initial point of the incursion. Should trace-back enquires lead to detection of the psyllid or disease in a nursery,

orchard or retail outlet, additional delimiting surveys should be undertaken at these locations and at locations to which or from which, plants or budwood may have been distributed.

Should trace-backs suggest possible airborne entry of *D. citri* from regions to the north of Australia, the Bureau of Meteorology should be consulted to determine the meteorological pathway involved and possible additional incursion sites.

The Bureau of Meteorology, NAQS, and other relevant State and Commonwealth authorities should collaborate to assess the risk of wind-borne incursions of *D. citri* and develop an 'early warning' system for an incursion of the vector and HLB. Such assessments should take into account the natural and cultivated distributions of known hosts, particularly species of *Citrus* and *Murraya* (*sensu stricto*), and of *B. koenigii* and *Cl. lansium*. Relevant information should be incorporated into awareness programs.

Immediate consideration, possibly before completion of the delimiting survey, should be given to application of pesticides currently registered for control of scales and other pests (e.g., the organophosphates azinphos-methyl, chlorpyrifos and methidathion, the carbamate carbaryl, and the neonicotinoid imidacloprid) in Australian citrus orchards, as recommended in Appendix XI, to kill psyllid eggs, nymphs and adults if the distribution of the psyllid appears to be limited in area or restricted to few host plants. The pesticides should be applied to

- all infested host plants; and
- uninfested hosts in,
 - neighbouring gardens and parks within 100 m of the infestation if the detection is in a home garden or park, and
 - all blocks in an orchard and any location⁸¹ where host plants are present within 100 m of the infestation.

Survey Methodology for Psyllids

Survey methodologies can comprise:

- visual inspections for adults on mature leaves, particularly on the underside of leaves in between flush cycles, particularly in regions with distinct winters;
- visual inspections for eggs, nymphs on flush growth from 5 mm to 50 mm long, particularly in spring, within 14 days of buds opening;
- visual inspections of young flush growth (5 mm to 50 mm long) for honeydew, particularly in spring, within 14 days of buds opening;
- beating foliage, particularly young flush growth, to dislodge adults into a 300 mm-diameter pan containing a shallow amount of mineral oil;
- use of D-vac machines to suck psyllid adults from within canopies; and
- use of yellow sticky traps to trap flying adults (see Aubert & Xia 1990, Catling, Samways 1990).

Each method has limitations governed by:

- the extent of an incursion and distributions of psyllids on hosts within the vicinity of the incursion (e.g., contagious (aggregated) distributions of infestations within urban areas or within an orchard where psyllids may be present on some trees but not on others); and
- availability of personnel to undertake surveys.

⁸¹ Location = (a) a block of trees of any variety within an orchard owned by an individual or company, (b) a home garden, a town or suburban park, a nursery, or (c) single or clumps of rutaceous hosts (*Citrus* and *Citrus* relatives) within 1 ha area of farmland, bushland or national park.

In southern California, the following methodology was used after the first detection of *D. citri* (Polek & Luque-Williams 2008):

California Response to Asian Citrus Psyllid Find in Tijuana, Mexico 1. Visual and sweeping survey in an area 5 miles north of the border with Tijuana and 12 miles from the ocean to inland areas. 2. Detection trapping survey started placing one yellow panel trap in each of the Mediterranean fruit fly trapping sites with a density of 5 traps per square mile. 3. The first ACP was found on a YP trap in South San Diego Area (11 miles north of the border).	Asian Citrus Psyllid Found in California 1. A visual survey in an 800 meters radius around the find site (core area) was initiated. The survey was done door-to-door, inspecting all the hosts in each location, tapping and placing one YP trap. 2. This was followed by a delimitation survey in a 9 square mile area including the core and buffer areas. Forty traps per square mile were placed. 3. As the delimitation survey progressed a D-vac device was incorporated and approximately 100 residences with host plants per grid were surveyed within the 800 meter radius of the quarantine area.
Quarantine Regulations 1. A State Interior quarantine for ACP was put in place covering 3764 square miles of San Diego and Imperial Counties . 2. No movement of citrus or citrus relatives outside of the quarantine area was permitted. 3. ACP host plants are required to be treated with an approved chemical under specific supervision before movement can occur within the quarantine area. 4. All harvested citrus in the quarantine area must be processed and packed before movement outside of the quarantine area.	Psyllid Control 1. Chemical treatment was implemented for all host plants at a detection site. 2. Foliar application with the organic compound PyGanic is applied every seven days. 3. One soil drench of Merit 2F(imidacloprid), a systemic product. 4. Foliar treatments with Tempo, a synthetic pyrethroid for every host within 400m radius of each find site.

We recommend that surveys to determine the extent of an incursion immediately after detection should involve, where feasible, both visual inspection of young flush growth for the presence of eggs, nymphs, honeydew adults, and beating of foliage, on hosts within 5 km of the point of detection using the protocols outlined above.

The usefulness of sticky traps in urban situations and orchards is limited by the distances *D. citri* and *T. erytrae* can fly, and on their need to disperse from a host plant. Their use in nurseries (open or screened) and small urban areas (e.g., in the coastal regions of northern Australia) would be appropriate if inspected every 7 d.

Usefulness of D-vacs machines will be limited by the number of trees to be sampled and would not be practical in urban situations, nurseries, or orchards unless used to sample large numbers of trees collectively to determine the presence of adult psyllids in a defined area.

In Texas in 2008, two survey programs are being run. In one, surveys in the commercial orchards and counties outside the Lower Rio Grande Valley are being undertaken, led by Texas A & M University. In addition, an intensive survey of residential sites in the cities of the Lower Rio Grande Valley is being conducted by a 30-member team led by USDA-APHIS in which 72 trees/square mile are being selected as sentinel trees in 93 1-square mile blocks (da Graça et al. 2008).

Survey Methodology for HLB

General references

- Floyd J, Krass C. 2006. New Pest Response Guidelines: Huanglongbing Disease of Citrus. USDA/APHIS/PPQ-Emergency and Domestic Programs, Riverdale, Maryland. (http://www.aphis.usda.gov/import_export/plants/ppq_manuals.shtml).
- Parnell SR, Riley T, Gottwald TR. 2007. Large-scale surveys for multiple pest species; the search for citrus canker and huanglongbing in Florida. American Phytopathological Society Annual Meeting.

Recommended Post- Incursion Pre-endemic Delimiting Survey Methodology for HLB

Trained surveillance teams should traverse orchards, nurseries, parks and gardens on foot looking for the following HLB symptoms (see Figs 18 to 28):

- yellow shoots
- mottled leaves
- small sometimes misshapen fruits with aborted seeds and darkening of the columella, and
- evidence of citrus psyllids or their activity.

If trees are more than 2 m tall, a tractor-mounted platform (e.g., Fig. 50) should be used to supplement ground surveys (Belasque 2006, Yates et al. 2008).



Figure 50. Survey platform as used in Brazil (photo: Pat Barkley).

Only symptomatic leaves with blotchy mottle symptoms should be relied on for positive PCR results for '*Ca. Liberibacter*' and these should be specifically collected. Symptoms become evident on younger plants sooner after infection than on mature trees, especially if budwood was infected, so younger plants should be included. It must be remembered that positive detection from symptomatic plants may lag up to 2 years or more behind infection.

Positive PCR results for HLB pathogens in psyllids may also provide indicative information regarding the likely area exposed to infection (Manjunath et al. 2008a). The results of Manjunath et al. (2008a) show that:

‘while a positive result from a psyllid analysis may be informative and useful for undertaking appropriate management decisions, negative results may not indicate absence of HLB activity in an area. Further, HLB movement in an area can be identified by psyllid analysis about one to several years prior to appearance of symptoms. The ideal time of psyllid sampling, sample size, and other parameters need to be determined. Assuming the lack of transovarial transmission (Hung et al. 2004, Xu et al. 1988), psyllid nymphs, which do not move from plant to plant, may acquire ‘*Ca. L. asiaticus*’ only from the tree on which they live. A nymph sample with ‘*Ca. L. asiaticus*’ would indicate that the source plant is infected, while an adult with ‘*Ca. L. asiaticus*’ may indicate only the presence of infected trees in the vicinity.’

In Florida, the 2007 Huanglongbing Technical Working Group agreed that the use of *D. citri* to detect incipient infections of HLB in areas where the disease is not known to occur is a potentially useful survey tool. However, the amount of bacteria in single infected psyllid can be near or below the current detection limits of real-time PCR technology, and confirmation of positive finds needed for regulatory actions may be problematic⁸². In addition, diagnostic results from psyllid surveys using current technology may have a high and possibly unacceptable false negative rate. In Florida the highest percentage of HLB positives from plant samples were collected in late summer and early autumn after a flush occurred. Positive psyllid samples collected during the spring months were at a lower percentage. Periods when host plants are in active flushes of growth appear to affect the ability to detect the bacterium. A drop in bacterial titre during flush is commonly observed. This corresponds to periods of the maximum psyllid population growth. The ability to detect the bacteria in plants increased if collected just after a flush, with the fall flush (August and September) more conducive than the spring flush.

Halbert & Manjunath (2004) cite research that yellow sticky traps worked best on sunny days whereas ‘brown yellow’ traps worked best on cloudy days. The optimum height for capture is 1.5 m (Aubert & Xia 1990). As noted previously, using sticky trap specimens to assay for HLB is problematic. First, the pathogen loses detectability if the trapped psyllid specimen is not processed by DNA extraction soon after trapping. In addition, only adults will be caught in this manner and may not be directly associated with a host plant. Consideration was given to this trapping method being used in areas where psyllids are not known to occur and where nodes of host movement occur, for example in packing houses and where unwashed fruit shipments are stored. For this situation, yellow sticky traps would be the most appropriate type to use. However, we regard field inspections of trees as more effective than traps, as a means for detecting or surveying for both *D. citri* and *T. erytrae* particularly in winter. All life cycle stages of the psyllids, honeydew and leaf distortions can be observed in field inspections. Only adults can be trapped.

Qureshi & Stansly (2007, 2008) used a simple ‘tap’ method for detecting and assessing *D. citri* populations in Florida.

Inspections at packing houses or juicing factories can provide an opportunity to detect adult psyllids as well as HLB affected fruit, and allow affected production areas to be identified.

During 2008, a National Plan to detect HLB in Mexico was launched with:

- extensive surveillance for the detection of symptoms of HLB;
- sampling of plants for symptomatic diagnostic;
- sampling of psyllids for asymptomatic diagnostic; and

⁸² Benyon et al. (2008) noted that nested PCR is essential to detect ‘*Ca. L. asiaticus*’ in psyllids that carry a low titre of the bacterium.

- establishment of Epidemiological Surveillance Plant Sites, with trees checked every 2 months and psyllid sampled every 3 months by 150 survey personnel (Robles et al. 2008).

Recommendations for Australian surveys

During survey activities it is important to count on specialists with knowledge of the targeted disease, as well as properly trained personnel (Floyd & Krass 2006). Surveyors should be trained not only on symptom recognition, but also on the biology of the pathogen and the insect vector. Some additional subjects recommended are citrus disease differentiation and host identification (Gomez 2008).

AWARENESS

About two thirds of plant pest incursions in Australia over the past 15 years were detected incidentally, rather than as part of a surveillance program and the majority of these incidental detections were made by the private sector (e.g., growers, agri-industry and general public) (Pheloung 2004). Incidental detections are generally unlikely until after the pest population has grown to levels noticeable to individuals who are not specifically looking for something unusual. This can mean that the benefits of early detection are lost. So, it is particularly important that growers, nurserymen, pest scouts, horticulturists and others are aware of HLB and its vectors, and have extension material readily available to them in a format aimed specifically at the respective audience.

General surveillance can effectively capitalise on other activities, such as crop monitoring for established pests in situations where people have the capacity to recognise new pests.

Raising public awareness generally and specifically through the preparation and distribution of booklets and fact sheets on particular plant pests is a central component of general surveillance. However, in the case of HLB and its vectors, we believe that there should be a 2-phased roll-out of awareness material. As part of pre-incursion first phase we have produced a simple bookmark on *D. citri*: 5000 copies have been distributed—

- at the 2008 Australian Citrus Grower's Conference at Griffith in October 2008,
- to growers through Australian Citrus News, and
- to nurserymen producing citrus through Auscitrus



Distribution of a brochure of HLB symptoms is not warranted before an incursion as symptoms of HLB are too similar to Australian citrus dieback and nutrient deficiencies. As a pre-emptive measure, resource material should be produced on HLB and its vector before an incursion occurs. The production and dissemination of resource material on HLB and its vectors should be co-ordinated between the states, OCPPO, PHA and industry and should be targeted at e.g., citrus nurserymen, growers and consultants and should be informative without being too technical.

Pre-Incursion Awareness Needs

The following are required:

- training of inspectors, horticulturists, CITTgroup co-ordinators, and IPM scouts by (a) pathologists with field experience with HLB and knowledgeable in disease symptomatology and epidemiology and awareness of diseases/disorders with which HLB can be confused, and (b) entomologists with knowledge of the biology, ecology and management of the vectors;
- training of growers and nurserymen in vulnerable areas e.g., Ord River, Darwin, northern Queensland;
- collation of internationally available DVDs, pamphlets and other extension material on HLB and the vectors of the pathogens for immediate distribution in the event of an incursion; and
- collaboration of PHA, OCPPO, AQIS, State Departments and industry to produce the one set of informative awareness material aimed specifically at growers, nurserymen and the general public.

Post-Incursion Awareness

HLB has not been eradicated in any country. The best control strategy is speedy elimination of symptomatic trees with frequent re-surveys. This means that once HLB has been detected in a region, or on a farm, growers must be constantly alert. They must be aware of the problem, symptoms of the disease and characteristics of the vector, and they must co-operate in the surveillance and eradication (Bergamaschi 2006, Lopes 2006).

Training farm workers in symptom recognition is essential and should be an immediate response to a positive finding of HLB and/or its vectors. Two excellent DVDs on disease recognition are available, one produced by Fundecitrus (Brazil), the other by the University of Florida, Lake Alfred. Copies are available in Australia and held by QDPI (Ceri Pearce & Andrew Miles), UWS (Andrew Beattie & Paul Holford), Australian Citrus Growers (Mildura office, and through Pat Barkley), or <http://www.doacs.state.fl.us/pi/videos.html>.

In **South Africa**, information on HLB is distributed through technology transfer groups, South African Fruit Journal (extension briefs), CRi net (only to growers), Citrus Research International (CRI) website, CRI Newsletter, citrus research symposia (held every second year). le Roux et al. (2006) stated that an awareness program using roadside signs on the main traffic routes to Cape Town would have slowed the spread of HLB to the Cape Province of South Africa.

The awareness program conducted in **Brazil**, was outlined by Bergamaschi (2006). Fundecitrus (the citrus grower organisation) began making the growers aware of HLB in July 2004 with the distribution of a folder containing information about disease importance, symptom recognition and management measures. In August and December 2004, Fundecitrus organised 2 international symposia on HLB with experts from South Africa, USA and France. In February 2005, a lecture cycle in collaboration with rural syndicates was begun, with 60 lectures to more than 2100 citrus growers and technicians. Fundecitrus has also offered training for inspectors to recognize the disease in the field and has trained more than 3000 inspectors. In May 2005, a communication campaign through TV, radio and the press was begun. In January 2006, a team of horticulturists was created to increase the knowledge and consciousness of the disease through farm visits - 1350 farms have been visited. In May 2006, a campaign was begun to eliminate orange jasmine, used as street trees in urban areas, by working with local mayors.

In preparation for the spread of *D. citri*, and possible detection of HLB, the California Citrus Research Board produced, in August 2008, downloadable documents (including brochures, bookmarks and posters) in English, Spanish and Chinese⁸³. In March of 2007 and again in March, 2008 California Citrus Mutual coordinated the Citrus Showcase, the industry's largest educational event. At these two events, workshops were held on HLB, its seriousness, the role of the Asiatic citrus psyllid, actions undertaken in Florida and Mexico, research projects being undertaken around the world and possible action steps for the California industry. At each workshop approximately 200 growers and industry members were in attendance. With the advent of *D. citri* into southern California, the Citrus Research Board of California is coordinating the industry's multi-pronged effort against the psyllid, a task that the Executive Officer of CRB considers could require US \$1.5 million annually. The plan includes a public outreach campaign, conducted by a public relations firm, aimed at helping urban residents spot the pest in their yards and ramped up field efforts to augment the work of the US Department of Agriculture and the California Department of Food and Agriculture.

In Australia, the following awareness strategies should be undertaken:

- distribution, to citrus growers and nurserymen, of folders/pamphlets containing information about the importance of the disease, symptom recognition, and disease management;

⁸³ see: <http://www.californiacitrusthreat.com/asian-citrus-psyllid.html>.

- training of additional inspectors and scouts (government and industry);
- distribution of a pamphlet for home gardeners, landscapers, park managers, retail nurseries, chain stores (e.g. Bunnings and Woolworths), to address quarantine risks posed by orange jasmine as well as citrus;
- regional seminars organised by CITTgroup co-ordinators in conjunction with state department of agriculture personnel, for citrus growers, nurserymen and their staff;
- orchard and nursery visits to increase the knowledge and consciousness of citrus growers and nurserymen about the disease, its potential economic impact and the vector;
- free diagnostic checks on suspect material;
- radio and TV e.g., Country Hour, Landline, Graeme Ross, and ABC Gardening Show to reach home gardeners, landscapers as well as growers and nurserymen;
- print media e.g., Australian Citrus News, rural newsletters, and the Land, Good Fruit & Vegetable, Australian Horticulture; and
- on-line information e.g., Citrus Board of South Australia and Murray Valley Citrus Board weekly emails to growers.

Current HLB Awareness Material in Australia

PaDIL - Pests and Diseases Image Library

PaDIL (<http://www.padil.gov.au/>) is an image based website designed to create a 'virtual reference collection of pests and diseases'. The primary aims of the website are twofold:

- to significantly improve the rapid recognition of pests and diseases that are of concern to plant health in Australia; and
- to broaden the base of people who can assist with the recognition of these pests.

The use of images, as well as common and scientific names, means that a wide range of people involved in plant health from farmers and importers/exporters through to inspectors and scientists can be involved in recognising pests and diseases. The web user can query for an individual species, or an entire group of species, or a mixed assemblage of species, or hosts, or world and local bioregions.

In addition to the images, authors provide a description of each pest or disease and notes on its distribution and host preferences. They also include useful references and websites. The finished webpage provides the user with a wealth of colour images and information specific to the pest or disease.

The current PaDIL site for HLB⁸⁴ and *D. citri*⁸⁵ must be revised to include more recent and extensive information provided within this incursion management plan. PaDIL also needs to include *T. erytreae*.

DAFF - Northern Australia Quarantine Strategy (NAQS) Fact Sheets

DAFF websites on HLB⁸⁶ and *D. citri*⁸⁷ should be revised as recommended above for PaDIL

⁸⁴ <http://www.padil.gov.au/viewPestDiagnosticImages.aspx?id=494>

⁸⁵ <http://www.padil.gov.au/viewPestDiagnosticImages.aspx?id=76>

⁸⁶ <http://www.daff.gov.au/aqis/quarantine/naqs/naqs-fact-sheets/citrus-greening>

⁸⁷ http://www.daff.gov.au/aqis/quarantine/naqs/naqs-fact-sheets/pests_of_plants_asian_citrus_psyllid

NAQS is responsible for the delivery of quarantine public awareness in the form of education and extension campaigns in the field in the areas its staff survey. The objectives of the Public Awareness Program are to improve knowledge and understanding of quarantine risks among northern Australian communities, to foster community support for NAQS operations and field work, and to encourage reporting by northern communities of abnormal conditions in animals and plants or the presence of unfamiliar craft and people with potential to introduce exotic pests and diseases. Since 1992, the Top Watch theme and associated logo have been used to brand NAQS Awareness activities and products. Further information on the NAQS program can be obtained from the Australian Quarantine and Inspection Service website at <http://www.aqis.gov.au/naqs>.

ERADICATION

Factors influencing decisions on eradication or containment will be:

- a pre-incursion cost/benefit analysis establishing significant economic loss to the citrus, nursery and allied industries or the community if the organisms establish;
- physical barriers and/or discontinuity of hosts that occur between production districts (see scenarios below);
- the degree of isolation of the area affected by an incursion, size of orchards, and a relatively low number of growers and households;
- difficult to achieve cost-effective control of the disease and its vectors;
- no primary parasitoids in Australia that will parasitise the vectors;
- outbreak(s) few and confined;
- trace back information indicating few opportunities for secondary spread;
- weather records show unfavourable conditions for pest and disease development and wider spread; and
- ease of access to outbreak site and location of alternative hosts.

Factors favouring alternative actions will be:

- outbreaks numerous and widely disperse;
- trace back information indicates extensive opportunities for secondary spread;
- weather records show optimum conditions for pest and disease development and spread; and
- terrain difficult and/or problems accessing and locating host plants.

Prior to an incursion, a cost/benefit analysis should be undertaken for each scenario outlined below (to determine if significant economic loss to industry or the community will occur if the organism establishes in one or more of the regions).

Prior response and eradication agreements must be established between industry and all levels of government and the immediate response must assume that eradication is possible, until delimiting surveys have been completed.

PlantPlan Version 1 2008, Section 2.2.2 — Adoption of Precautionary Measures, states that:

‘if the pest is considered an EPP and potentially serious, then precautionary measures should be implemented as soon as possible. while identification and delimiting surveys are undertaken’.

Should psyllids be detected, adults and nymphs should be collected, for formal identification and for PCR tests for the presence of the HLB pathogen, before application of pesticides.

When eradication of *D. citri*, in the absence of HLB, is considered in the scenarios below, it is recommended that such action should be based on:

- quarantining the property or properties where the psyllid occurs so as to prevent the removal of any HLB host plants, budwood, or psyllid vector hosts.
- immediate application of insecticides (e.g., the organophosphates azinphos-methyl, chlorpyrifos and methidathion, the carbamate carbaryl, and the neonicotinoid imidacloprid) to all host plants (these pesticides will be applied as foliar sprays using backpack applicators, by employees or agents of the commercial plant nursery or orchard, other ground equipment, or through soil drench by watering or dipping);⁸⁸.
- skeletonisation of all *Citrus* trees in orchards, home gardens and elsewhere (excluding nurseries);
- skeletonisation of, and removal of all leaves from, grafted *Citrus* trees, and destruction of all small seedling rootstocks, in nurseries; and
- removal of all *Murraya* and *Bergera* shrubs and trees.

Such action should optimise the prospect of eradication, as the psyllid cannot survive in the absence of host canopies. Skeletonising, as an alternative to tree eradication, will minimise costs and allow orchards and nurseries to return to full production sooner.

It may be feasible to use defoliant in such circumstances in orchards (see Cooper et al. 1968, Graham et al. 2008) to achieve rapid removal of foliage on which the psyllid depends. However, there are currently no registered defoliant for citrus and doses (concentrations and spray volumes) would need to be determined. Outcomes are likely to be variable depending on chemical rate, spray application method, tree age, water relations and environmental conditions at time of application (Graham et al. 2008). It may be possible to apply defoliant with insecticides, but the feasibility of such tank mixes would need to be carefully considered.

Quarantine Zones

Upon detection of *D. citri*, *T. erythrae* and/or HLB, a quarantine zone (restricted area) prohibiting the movement of any part of a host plant, including fresh fruit, should be established immediately and maintained until a decision is made as to whether eradication is feasible. Decisions to eradicate will depend on the most likely source of the infestation and possible multiple sites of infestation that could occur with distribution of infested plants from nurseries or airborne incursions via, for example, tropical cyclones. Therefore, patterns of distributions and likely sources of infestations will need to be determined by ‘trace-back’ in terms of sources of infested plants and meteorological records.

Scenarios

Eradication or containment has been considered under the following scenarios, provided here as examples.

- A. In isolated coastal regions in northern Australia (e.g., Thursday Island and Bamaga on Cape York in Queensland, Melville Island in the Northern Territory, and Derby in Western Australia) where:
 - o the distribution of *Citrus* and *Citrus* relatives would be sparse in native vegetation, parks and home gardens within a 5 km radius (80 km²) of a single initial point of detection; and

⁸⁸ The potential environmental effects of these pesticides is summarised in the ‘USDA Citrus Greening Control Program in Florida Nurseries. Environmental Assessment January, 2006 http://www.aphis.usda.gov/plant_health/ea/downloads/citrusgreening1-06ea.pdf.

- o with the immediate establishment of a quarantine zone encompassing the area within a 20 km radius of the point of initial detection.
- B. In isolated minor horticultural regions (e.g., Lambells Lagoon near Darwin) where:
- o the distribution of *Citrus* and *Citrus* relatives in native vegetation, parks, home gardens and orchards is limited to an area within a 5 km radius (80 km²) of a single initial point of detection; and
 - o with the immediate establishment of a quarantine zone encompassing the area within a 20 km radius of the point of initial detection.
- C. In isolated minor citrus producing regions (e.g., Gin Gin, Carnarvon and Kununurra in Western Australia) where:
- o the distribution of *Citrus* and *Citrus* relatives in native vegetation, parks, home gardens and orchards is limited to riparian areas within a 15 km radius of a single initial point of detection; and
 - o with the immediate establishment of a quarantine zone encompassing the area within a 40 km radius of the point of initial detection, until a decision is made for eradication.
- D. Along the east coast of Australia where:
- o the distribution of *Citrus* (including native *C. australasica*, *C. australis*, *C. garrowayi* and *C. inodora*) and *Citrus* relatives in native vegetation, parks, home gardens and orchards is associated with cities, towns and villages within a 5 km radius (80 km²) of a single initial point of detection: and
 - o with the immediate establishment of a quarantine zone encompassing the area within a 20 km radius of the point of initial detection.
- E. In isolated major citrus regions (e.g., Emerald and Gayndah-Mundubbera, in Queensland) and smaller isolated centres (e.g. Hillston and Narromine in New South Wales), where there are relatively few orchards and where native citrus (e.g., *C. glauca*) may occur:
- o if infestations are recorded within a 10 km radius (314 km²) of a single initial point of detection; and
 - o with the immediate establishment of a quarantine zone encompassing the area within a 50 km radius of the point of initial detection.
- F. Within the southern Riverina (excluding Hillston), Riverland, Sunraysia and other Murray River districts, where there are numerous mixed, relatively small orchards, and where *C. glauca* may occur:
- o if infestations are recorded within a 5 km radius (80 km²) of a single initial point of detection;
 - o and with the immediate establishment of a quarantine zone encompassing the area within a 50 km radius of the point of initial detection.

A decision key for eradication of citrus psyllids and HLB is presented in Table 6.

Table 6. Decision key for eradication of citrus psyllids and HLB.

1	Psyllids and host plants test negative by PCR for liberibacters	2
	Psyllids and/or symptomatic host plants test positive by PCR for liberibacters	3
	Host plants test positive by PCR for liberibacters in the absence of psyllids	4
2	Psyllids are detected	
	in isolated coastal regions in northern Australia as defined in A above	EP
	in isolated minor horticultural regions as defined in B above	EP
	in isolated minor citrus producing regions as defined in C above	2A
	along the east coast of Australia as defined in D above	2B
	in isolated major citrus regions as defined in E above	2C
	within the southern Riverina (excluding Hillston), Riverland, Sunraysia and other Murray River districts as defined in F above	2D
2i	C: psyllids are detected at:	
	< 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	EP
	> 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	EP
2ii	D: psyllids are detected at:	
	< 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	EP
	> 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	CE
2iii	E: psyllids are detected at:	
	< 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	EP
	> 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	EP
2iv	F: psyllids are detected at:	
	< 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	EP
	> 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	CE
3	HLB positive plants and/or psyllids are detected	
	in isolated coastal regions in northern Australia as defined in A above	EH
	in isolated minor horticultural regions as defined in B above	EH
	in isolated minor citrus producing regions as defined in C above	
	along the east coast of Australia as defined in D above	
	in isolated major citrus regions as defined in E above	
	within the southern Riverina (excluding Hillston), Riverland, Sunraysia and other Murray River districts as defined in F above	
3i	C: detections at:	
	< 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	SPEH
	> 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	SPEH
3ii	D: detections at:	
	< 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	SPEH
	> 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	SPEH
3iii	E: detections at:	
	< 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	SPEH
	> 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	SPEH
3iv	F: detections at:	
	< 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	SPEH
	> 10 survey points, each 1 km or more apart, within a radius of 5 km of the initial detection	SPEH
4	Eradicate all positive hosts, and all plants propagated from these trees ('trace-forward'); complete 'trace-back' surveys to determine and eradicate the source of infection	EH
	Two sites?	

EP=eradication of psyllid recommended under cost sharing agreement (CSA); CE=consider eradication of psyllid under CSA; SPEH: Adopt psyllid only eradication protocols where negative psyllids are found with asymptomatic hosts; spray and eradicate hosts where positive psyllids and/or hosts are found; consider spraying and removal of hosts when in doubt. Here, decisions will depend on identification of the foci of infected psyllids and/or hosts ('hotspots').

Detection in a backyard urban area

If HLB and/or *D. citri* is detected in a backyard in an urban area then door-to-door delimiting surveys need to be conducted on all hosts (fruiting citrus, curry leaf, kaffir lime, orange jasmine and other hosts listed in Appendices VI and VII) on all properties within a defined radius (see Post-incursion Pre-endemic Delimiting Surveys) of the infested premises.

Trace-backs may help determine the source of the infection on the backyard citrus trees. Planting material, natural dispersal and human activity must all be considered as potential sources of infection.

Detection in a backyard urban area near a commercial area

In the event of an outbreak occurring in an area surrounded by, or in close proximity to, commercial plantings of citrus, delimiting surveys will need to be conducted over a wider area than an urban scenario. The survey should also extend into these commercial areas to determine the extent of the outbreak.

All hosts including citrus relatives e.g., *Murraya* sp. within a defined radius (see Post-incursion Pre-endemic Delimiting Surveys) of the infested premises need to be surveyed for symptoms of HLB or the vector. Commercial areas outside the defined distance for delimiting surveys will also need to be inspected but not as rigorously as those within the initial survey zone. If HLB and/or *D. citri* are found in a commercial grove during the delimiting survey then further action should be taken as below.

Trace-backs may help determine the source of the infection on the backyard citrus trees. Planting material, natural dispersal and human activity must all be considered as potential sources of infection.

Detection in a commercial orchard

When HLB and/or *D. citri* is positively identified in a commercial orchard or farm (commercial fruit production, kaffir lime leaf production, budwood supply), then a delimiting survey (as above) will be conducted to determine the extent of the outbreak and tracing procedures implemented to determine the source of the infection and identify contact, and suspect premises.

All hosts, including those in abandoned citrus orchards, feral citrus and native vegetation (e.g., desert lime, finger lime) within a defined distance (see Post-incursion Pre-endemic Delimiting Surveys) of the boundary of the infested premises must be surveyed, as well as other properties owned or managed by operators of the infested premises.

All commercial groves and residential sites beyond a defined distance of the infested premises are to be surveyed on a less rigorous basis (e.g., every second or third row or fifth row of commercial groves). Backyards of people working on infested properties are considered contact and suspect premises and should be inspected accordingly.

Trace-backs may help determine the source of the infection on the backyard citrus trees. Planting material, natural dispersal and human activity must all be considered as potential sources of infection.

Detection in a nursery (wholesale, retail)

When visiting nurseries to conduct surveys or to collect samples, regulatory officials must take strict measures to prevent movement by plant pathogens between properties during inspections (Telford 2007⁸⁹ outlines precautions to be taken in regard to citrus canker, but these precautions are equally applicable to other pathogens). In addition, viroids—small pieces of naked RNA similar to a plant virus but lacking the protein coat—are extremely difficult to remove from tools. Most disinfectants, as well as heat, fail to inactivate viroids. When collecting samples, pruning shears should be disinfected between cuts and prior to use on a new property, to avoid spreading citrus exocortis or other citrus viroids. These citrus pathogens can be carried on the cutting surfaces of pruning shears, knives, and other implements used for cutting and pruning operations. Making a cut on an infected tree is sufficient to contaminate the cutting tool; subsequent cuts on other trees will introduce the viroid and infect the tree. A 10% solution of common household bleach (sodium hypochlorite with 1-2% available chlorine) should be used to inactivate citrus viroids.

When HLB and/or *D. citri* is discovered in a nursery or retail premises, then all hosts including citrus relatives on the premises must be inspected. All commercial groves and residential areas within a defined distance (see Post- incursion Pre-endemic Delimiting Surveys) of the infested premises must be surveyed for the presence of HLB and/or *D. citri*. All nurseries beyond those covered by the initial delimiting survey should also be thoroughly inspected, due to the potential for widespread movement of this material.

Trace-back and trace-forward procedures are particularly important when delimiting surveys are conducted on these sites given the potential widespread distribution of planting material from nurseries. Records of sales will be inspected to identify contact and suspect premises and sources of budwood and seed. Sales to retail chains and subsequent distribution must be traced.

Detection in a packing shed or juice factory

It is possible that *D. citri* could be present in bulk bins of fruit received at a packing shed or juice factory because bulk fruit frequently arrive with leaves or branches in the bins. Psyllids can survive deep within a container of fruit, even with no leaf material present (Halbert, pers. comm., 2006). If *D. citri* is found in a load of fruit bins or trucks must be covered and fumigated immediately⁹⁰. Alternatively the packing shed or juice factory could observe that a consignment has a proportion of small lopsided poorly coloured fruit with a bitter taste, probably because of higher acidity and lower sugars. Trace back to farm of origin and block would be essential.

⁸⁹ Telford G. 2007 Decontamination and Hygiene Requirements When Conducting a Survey for Citrus Canker. QDPI&F Work Instruction ST-W-006.

⁹⁰ Yellow sticky traps can be used to detect psyllid in packing sheds.

Monitoring e-commerce sales of citrus material

In the USA, a USDA SITC program monitors e-commerce sales of plant material for illegal movement.

Weekend markets selling citrus trees, *Murraya* spp. or kaffir lime leaves

Weekend markets with multiple sellers across Australia are unregulated and disengaged from normal citrus nursery and fruit production organisations. As such, they pose a threat to any eradication attempts. These markets must be inspected.

Trace-backs

Trace-back analysis will help determine if the HLB pathogen and/or *D. citri* originated from material sold commercially, from natural dispersal or by human activity, including illegal introductions of planting material. It is likely that the first reported case will not be the initial source. This is important for identifying the origin of the outbreak and locating other infested sites.

Storm or cyclone activity must also be considered.

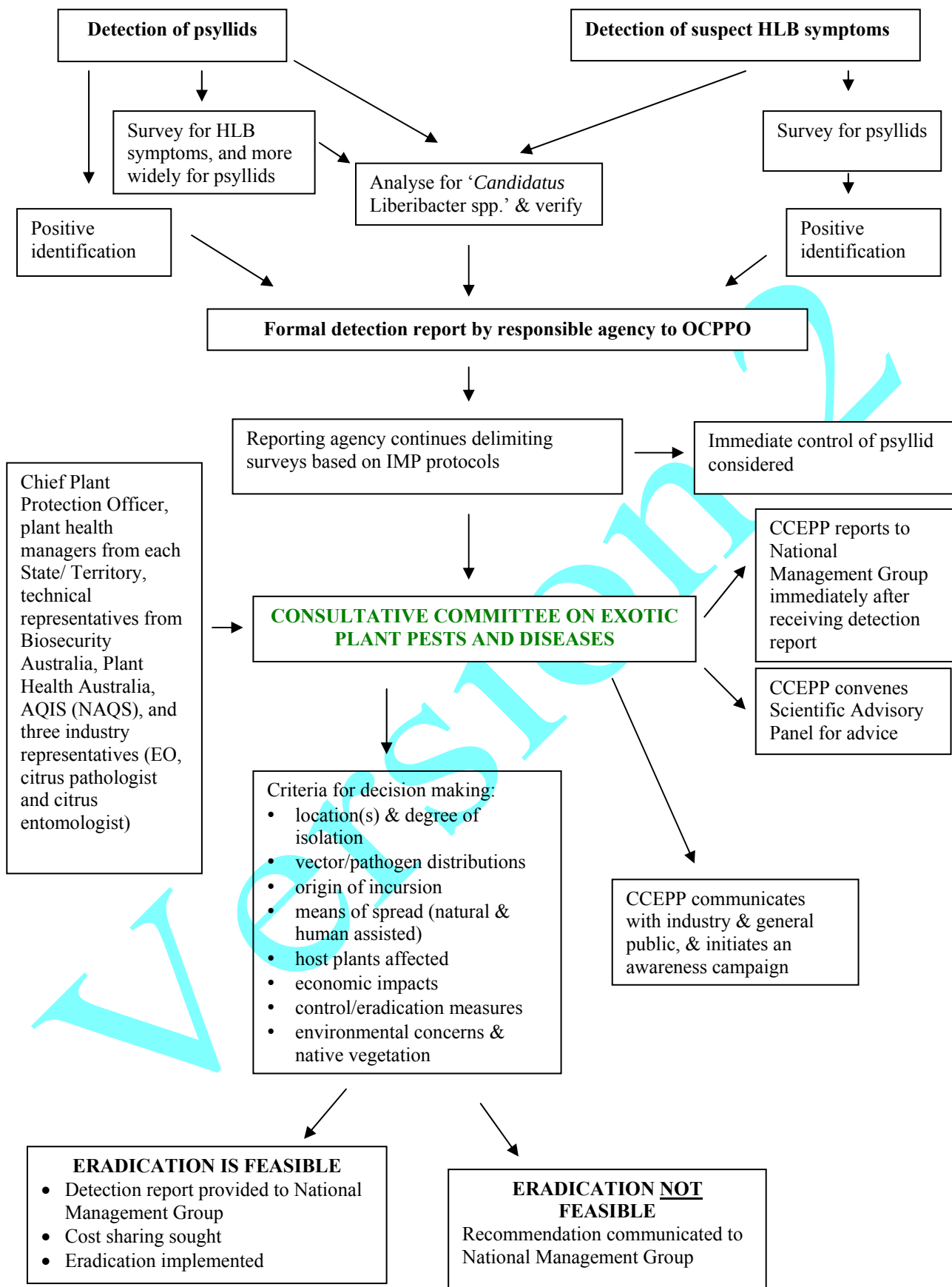
Details of trace-back interviews are recorded on the Survey Form by State quarantine personnel (Appendix 1) and forwarded to the State Quarantine Manager. Records from trace-back interviews are analysed by AQIS and the Consultative Committee and used to identify contact and suspect premises; and, if necessary, to modify the boundaries of the restricted and control area. Information is also used to assist in planning of surveys in areas surrounding newly identified contact premises and suspect premises.

Analysis of HLB symptoms may be useful for determining the age of the infection site and for conducting trace-back analysis. Symptoms on residential trees are not as predictable as commercial plants because of varying levels of horticultural care. The lag in time between transmission by psyllid vectors or propagation and the onset of symptoms can be quite variable and quantifying the severity of disease symptoms in individual trees may not be a true indication of pathogen concentration.

Shipment of Hosts of Asiatic or African Citrus Psyllid

No movement of any insect vector hosts (e.g., *Citrus* spp., orange jasmine; see Appendices VI and VII) will be permitted from nurseries (retail and wholesale; weekend markets) in quarantined areas with confirmed detections of either *D. citri* or *T. erytraeae*. Movement of budwood, fruit, or fresh leaves for culinary purposes will also be prohibited.

Movement of nursery plants and fruit from outside the quarantine area in an affected state, could be considered, but movement should be under a limited permit requiring prescribed regulatory treatments (e.g., the organophosphates azinphos-methyl, chlorpyrifos and methidathion, the carbamate carbaryl, and the neonicotinoid imidacloprid).



Should *D. citri* or *T. erytrae* become more widespread in an area or state, movement of nursery plants and fruit, within that defined area could be considered, but movement should be under a limited permit requiring prescribed regulatory treatments (e.g., the organophosphates azinphos-methyl, chlorpyrifos and methidathion, the carbamate carbaryl, and the neonicotinoid imidacloprid).

LEGISLATION

This information is based on the Department of Agriculture, Fisheries and Forestry 'DAFF Submission to the Senate Rural and Regional Affairs and Transport Committee Inquiry into the Citrus Canker Outbreak'⁹¹. It indicates legislation available to deal with pest incursions. See also Table 2 dealing with legislation in the PHA Citrus Biosecurity Plan.

More specifically, critical powers in response to incursions of HLB and/or its vectors should:

- **'Require occupiers of any place within a declared area to take specified measures, including the treatment or destruction of plants and plant products, necessary for the control or eradication of an exotic pest.'** As part of a containment or eradication programme for an exotic pest, occupiers of affected properties will need to implement control measures that may include the application of pesticides and destruction of host plants. All State plant protection agencies have the legislative authority to require land owners or occupiers to take specified measures to control or eradicate an exotic pest and penalties may be imposed on a person for non-compliance.'
- **'Prohibit the planting or propagation of plants'⁹² within a declared area.** In order to contain or eradicate a newly introduced exotic pest, it is necessary to implement a range of measures to prevent the establishment and spread of the organism. This may include preventing the planting of host crops within the affected area for a period of one or more growing seasons. South Australia, Victoria, Tasmania and the Northern Territory have specific powers to prohibit the planting or propagation of plants, or reduce the number of plants, within a declared area over a specified time; for other States, legislative authority may be provided under general powers associated with control or eradication programmes for exotic pests.'
- **'Able to destroy healthy or apparently uninfested plants to prevent the spread of an exotic pest.'** For exotic pests that pose a high risk of spread, it may be necessary to destroy healthy host and volunteer plants surrounding the outbreak to create a buffer zone for containment or eradication. In some cases an eradication programme may not be able to proceed unless such a buffer can be established. The provisions of the State plant health Acts vary in relation to the removal of healthy plants and none has specific provisions for the creation of buffer zones. In Queensland, the Chief Executive has express powers to order the destruction of healthy plants, harvested crops and volunteer plants for the purpose of controlling an exotic disease (however, destruction of healthy plants is subject to payment of compensation – see Section 6.1.9). In South Australia, the Chief Inspector has legislative authority to order the destruction of plants that might become affected by a disease – the implications are that healthy plants may be destroyed. However, the powers of the other States are less clear. For example, government control programmes in Tasmania may involve measures to reduce the number of plants in an area, but it is not specified in the Plant Quarantine Act 1997 whether this includes healthy plants or not.'

Legislation should include destruction of abandoned/neglected orchards and home garden trees without the need to prove plants are infected or infested.

In Brazil, a 'HLB Suppression Program', headed by the Ministry of Agriculture, Secretary of Agriculture of SPS, and Fundecitrus was implemented shortly after the first report of the HLB in São Paulo State (Ribeiro 2006, Lopes et al. 2008). It was designed with the objective of eliminating all symptomatic trees in the affected areas, to avoid disease spread to other regions. Initially, the program involved talks and presentations to draw grower attention to importance of HLB, how to recognise disease symptoms, and the value of eliminating inoculum sources and vector populations. the demonstration that *M. paniculata* also hosts liberibacters, led to the promulgation, in 2005, of a federal normative instruction (IN10), making mandatory the elimination of all affected citrus trees, as well as of *M. paniculata* present in citrus farms. The identification of the symptomatic citrus

⁹¹ http://www.aph.gov.au/senate/committee/rrat_ctte/completed_inquiries/2004-07/citrus_canker/submissions/sub12.pdf

⁹² For example, orange jasmine, *M. paniculata*/*M. exotica*.

trees to be eliminated was based on at least two official inspections per year, in all farms of the municipalities where HLB was present. With the constant increase in the number of affected farms and, consequently, in the number of official inspectors required to cover all affected area, a second and still in progress federal normative instruction (IN32) was published. IN32 transferred to the grower all the responsibility of finding and eliminating the symptomatic trees, with these processes being carried out by official and Fundecitrus inspectors. The non-enforcement of the federal law is one of the main reasons for the occurrence of HLB infected farms without HLB control. A new federal law was approved in October 2008. The affected citrus blocks with HLB incidences higher than 28% of symptomatic trees must be completely uprooted. For lower incidences, only symptomatic trees must be removed (Belasque et al. 2008).

COST SHARING

In Australia, there is formal cost sharing agreement between the Australian citrus industry and the federal government. The agreement is based on an Emergency Plant Pest (EPP) Response Deed. It allows the Australian citrus industry to be directly involved in decision making, including biosecurity and risk reduction measures. It also reduces delays in securing funding and removes uncertainties and disincentives for growers to report suspected emergency plant pests. It only deals with responses to emergency pests covered by a cost sharing agreement. The relative share of the total cost of the incursion management that will be covered by industry and government respectively varies according to the public and private benefits to be obtained from eradication. A categorisation group is responsible for determining a cost sharing category applicable for high priority pests. Only emergency pests that have a high impact or establishment potential are considered for categorisation.

The Government and Plant Industry Cost Sharing Deed in respect of Emergency Plant Pest Responses lists '*Ca. Liberibacter asiaticus*' as category 2 for which 80% funding for managing an incursion is provided by the government and 20% by the industry, with the industry component comprising 97.1% from Australian Citrus Growers Inc. and 2.9 % from the Nursery and Garden Industry Association (PHA National Citrus Industry Biosecurity Plan: www.planthealthaustralia.com.au). In the PHA Emergency Plant Pest Response Deed - list of categorised pests, *D. citri* is listed as a category 3 pest. The other known pathogens that cause HLB, '*Ca. L. africanus*' and '*Ca. americanus*', and *T. erythrae* are not currently included in the EPP Plant Response Deed.

In the Cost Sharing Categories for Emergency Plant Pests, a key criterion for determining the pest category is the 'economic impacts on regions or the national economy'. The basis for this criterion is that where there are adverse regional impacts from a pest incursion, there is a case for government involvement because of the social costs and disruptions that occur to non-producer stakeholders. Without financial commitment from government, producers could incur the full cost of control measures, whilst other non-producer stakeholders could benefit from control measures without contributing to the cost of the control.

OWNER REIMBURSEMENT

The PHA Evidence Framework for Owner Reimbursement Costs for the Citrus Industry is generic and could be accepted in its current form. But the schedules of costs in the Appendices need to be clearly defined and current e.g., tree gross margin budgets and replanting costs in the Appendices are presently based on the 2003 NSW Citrus farm Budget Handbook.

POST-INCURSION MANAGEMENT OF ENDEMIC HLB AND ITS VECTORS

Surveys for endemic HLB

In **Brazil**, the first survey of blocks is 20% of trees i.e., for each 5 rows only one is inspected. If trees positive for HLB are found, then 100% of the trees are inspected. Bassanezi et al. (2006a) studied the effect of inspected sample size on the detection efficiency of blocks with HLB. As expected, as the number of rows inspected decreases, the probability of finding diseased trees decreases. This reduction was more significant when the incidence of symptomatic trees was less than 1%. In blocks with incidence more than 1%, an inspection of all trees of one of each 7 rows (14.3%) was enough to detect the presence of HLB symptomatic trees in more than 90% of blocks where the disease was present. Where the incidence was < 1%, the highest probability of detecting HLB in the block was obtained checking 50% of rows, with an escape rate of 15%.

In Florida, Southern Gardens is one of the largest citrus producers in Florida with 6712 ha comprising three large groves. HLB was first detected in the southernmost grove in November, 2005 in 7 trees on the eastern edge of the property. Immediately after the initial discovery, a system was put into place to scout and remove HLB infected trees in all three groves. The scouting process consists of visual identification of HLB infected trees by trained field scouts, followed by confirmation by 'senior scouts' which are more experienced and more highly trained inspectors. If the senior scouts confirm the diagnosis of the initial scouting crews, the trees are marked for removal and the latitude and longitude of the tree is recorded using a robust field computer running software specifically designed for the HLB scouting that incorporates a global positioning system (GPS). Thus the position of every infected tree can be located within the grove for each inspection cycle (Irey et al. 2008). Higher levels of infection were noted during all inspection cycles in trees less than 10 years of age. Higher incidences of HLB infected trees were observed associated with grove and block 'edges' i.e., where there was a break in the trees that created an interface between continuous trees and an open space, there tended to be an increase in infected trees. Examples of edges include grove and block boundaries, roads, irrigation ditches, ponds, interfaces with natural areas, and interfaces between young and mature trees. Some of these observations can be used in making scouting decisions e.g., to determine if HLB is present in an orchard for the first time, scouting efforts should be initially directed towards young trees and concentrating on edges may be warranted.

Effective management of HLB

This text is taken from Appendix XI in which management options for HLB and its vectors are reviewed.

Effective management of HLB requires:

- use of pathogen-free rootstocks and scions in lieu of potentially infected budwood, scions, and marcotts;
- frequent (e.g., 6 times annually) monitoring for HLB symptoms;
- prompt destruction (cutting down and poisoning of roots) of diseased trees within orchards;
- destruction of abandoned orchards
- use of windbreaks to restrict and slow psyllid dispersal⁹³;

⁹³ The effectiveness of windbreaks will depend on several conditions including canopy density, height, and spacing within and between breaks.

- propagation of plants, as interplants or ground-covers within orchards, that produce volatiles that repel adult psyllids; and
- use of sprayers (e.g., oscillating booms rather than airblast sprayers) that do not assist, or at least minimise, dispersal of adult psyllids in air currents.

These requirements are influenced by:

- potential for ingress of infected psyllids from surrounding areas (area-wide management);
- climate (rainfall, and seasonal temperatures and humidities);
- irrigation and nutrient management practices;
- flushing phenology and extent, including the number, size and shape of leaves, in relation to host plant species or hybrid, climate and management practices;
- impacts of tree size, canopy shape and planting densities on spread of the pathogen in trees;
- impacts of tree size, canopy shape and planting densities on application of chemicals to trees;
- hedging and pruning practices;
- the presence and effectiveness of natural enemies of the vectors;
- the extent of feeding and oviposition suppression by deposits of chemicals applied as sprays (e.g., mineral oils);
- doses of chemicals applied for psyllid control (e.g., for foliar applications, deposition of active ingredients on foliage in relation to concentrations of active ingredients in sprays and spray volumes per hectare);
- timing (e.g., as a new growth flush cycle commences) and methods of application (e.g., foliar, trunk or soil) of chemicals applied for psyllid control; and
- number, frequency and thoroughness of applications.

In the context of the above, and strategies endorsed by Kotze (1985), Whittle & Maharam (1988), Aubert (1990b), Ke & Xu (1990), Ke (1991), Xu et al. (1991), Buitendag & von Broembsen (1993), le Roux et al. (2006b), Roistacher (1996), Tersi (2006), Yang et al. (2006), Zhao (2006) and Gottwald et al. (2007), we make the following recommendations for control of HLB, and its vectors, in orchards where both the disease and one or both vectors occur:

- use of certified pathogen-free buds produced under a certified budwood scheme (no use of uncertified buds or marcotts);
- mandatory area-wide management practices (this will be difficult in Australia where orchard sizes are much smaller than in Brazil or Florida and where not all growers will diligently and effectively apply vector control measures);
- quarterly, or more frequent, monitoring by trained personnel of orchards for symptoms of HLB;
- use of PCR or, alternatively, if validated as appropriate, the iodine-starch test (IST) in conjunction with microscopy to detect phloem degeneration, to confirm HLB infection in symptomatic leaves;
- mandatory⁹⁴ and immediate destruction of HLB-infected trees (those that are PCR or IST positive) by cutting each trunk near its base and applying glyphosate to the stump to kill the roots (this must be done without waiting to harvest any mature fruit)⁹⁵;
- mandatory and immediate destruction of all trees in a block should the percentage of HLB-infected trees in a block reach or exceed 10% of trees within an interval of 12 months⁹⁶;
- mandatory destruction of abandoned orchards⁹⁷;
- mandatory removal of HLB-infected trees in home gardens;

⁹⁴ Legislation will be required for mandatory removal of plants even in the absence of a positive HLB record (e.g., abandoned orchards).

⁹⁵ In Brazil, eradication is mandated to be undertaken within 15 days of confirmation of infection.

⁹⁶ To prevent ingress of HLB into orchards from adjacent contaminated orchards all orchards must maintain rigorous eradication programs for HLB infected trees and maintain vector populations at very low levels (see Aubert 1990b, Bassanezi et al. 2007).

⁹⁷ As in Brazil: see Massari & Libanori (2006) and Ribeiro (2006).

- mandatory removal of alternative hosts of the vectors and liberibacters, particularly species of *Murraya*⁹⁸, *Bergera* and *Clausena*, within close proximity (2 km) of orchards⁹⁹;
- geographical isolation of budwood sources (mother trees); and their maintenance in insect-proof screenhouses;
- geographical isolation of nurseries from orchards, and of orchards from alternative hosts of the disease and its vectors;
- nursery production, in HLB affected regions, in secure insect-proof screenhouses (see section on effect on nurseries pp. 31-32 and 38-41, and Florida Citrus Health Response Plan);
- legislation to prohibit transport of HLB-infected or vector-infested plant parts (e.g., nursery trees, budwood, fruit and seeds) to unaffected areas;
- management of planting densities, canopy dimensions and canopy densities to optimise yields per hectare and effective application of sprays, and to minimise light intensities that favour psyllid infestations;
- planting of windbreaks to minimise movement of adult psyllids within and between orchards;
- hedging and pruning practices timed and undertaken to minimise the risk of enhancing vector populations;
- orchard and nursery management of *D. citri* and/or *T. erytrae* with strategically applied insecticides and mineral oils;
 - timing of sprays should be based on host-plant phenology so as to minimise feeding and oviposition and to maximise mortality of eggs, nymphs and adults;
 - application of sprays should be even and thorough, with sprays applied to run-off;
 - use of soil drenches and tree injections should be based on tree size and phenology, and account for potential loss or diminution of active ingredient(s) through leaching, degradation or tree growth;
- strategies to encourage, where feasible, biological control of the vectors by their natural enemies (e.g., planting of groundcover plants to encourage generalist predators);
- intercropping with plants that produce volatiles that repel the vectors, thereby slowing ingress of HLB into orchards;
- timing irrigation (where feasible) and fertiliser applications to regulate the timing, number and extent of flush cycles; use of supplementary overhead irrigation to reduce psyllid populations; and
- education of farm and nursery personnel; pesticide manufacturers, distributors and retailers; consultants, technical advisors, and scouts; research, quarantine, regulatory and advisory staff within government departments.

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⁹⁸ See Lopes (2008) for legislation enacted in Brazil which includes mandatory removal of *Murraya* street trees

⁹⁹ Excluding rare and endangered native species of *Citrus*.

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Appendices

Appendix I: Systematics of the genus *Citrus*

Appendix II: Origins of *Citrus*

Appendix III: Origins of huanglongbing

Appendix IV: Spread of huanglongbing in Asia

Appendix V: Hosts of huanglongbing

Appendix VI: Hosts of *D. citri*

Appendix VII: Hosts of *T. erytrae*

Appendix VIII: Origins of *D. citri* and *T. erytrae*

Appendix IX: Nomenclature, systematics and general biology of the Psylloidea

Appendix X: Biology and ecology of *D. citri* and *T. erytrae*

Appendix XI: Management of huanglongbing, *D. citri* and *T. erytrae*

Appendix XII: Australian Psylloidea: including *D. tryoni*

Appendix I: Systematics of the genus *Citrus* and some *Citrus* relatives

The genus *Citrus*¹⁰⁰

The most widely used taxonomic systems for classifying citrus are those of Walter Swingle (Swingle 1943, Swingle & Reece 1967) and Tyozauro Tanaka (Tanaka 1977). They recognised 16 and 162 species respectively. Their views have led to widespread confusion in the use of names of cultivar groups, inappropriate species status of hybrids, and the names of true species (Scora 1975, Mabberley 1997), and a profound misunderstanding of generic limits (Mabberley 1998). Confusion and turmoil has been exacerbated by the use of a plethora of species names for apomictic hybrid clones. There has been no consensus on the names of these entities and many dubious synonyms and invalid names are widely used in books, journals and, most recently, in poorly referenced and inconsistent popular and technical internet websites that could perpetuate errors *ad infinitum*. Some papers, including molecular studies, deal with plants for which claimed taxonomic relationships are invalid or poorly understood and for which verifiable voucher specimens have not been preserved. Many such publications are therefore of limited value and may mislead the unwary. Recent work suggests that the genus *Citrus* comprises about 25 species (Mabberley 2004). This view is based on (i) recent reunification of *Eremocitrus*, *Fortunella*, *Microcitrus* and *Poncirus* with *Citrus* (see Mabberley 1998), (ii) molecular studies by Guerra et al. (2000) and Samuel et al. (2001) that support these reunifications, and (iii) other molecular studies that suggest that the six species of *Oxanthera* from New Caledonia and the monotypic *Clymenia polyandra* (Tanaka) Swingle from New Ireland in eastern Papua New Guinea should be reunited with *Citrus* (see Mabberley 2004, Bayer 2004, Bayer et al. 2009). Australasia is therefore a ‘hot-spot’ for *Citrus* biodiversity with up to 13 endemic species (about 50% of all extant species) in the region. Most cultivated citrus is derived from the handful of Southeast Asian species (Table 1). The citron, *C. medica*, the first described species of *Citrus*, and long considered to be native to India, most probably originated in Australasia, possibly in New Guinea. Its closest relative is *C. polyandra*, a species native to New Ireland, a small island to the north-east of mainland Papua New Guinea (Bayer et al. 2009).

Common hybrids are listed in Table 2, and their origins illustrated in Fig. 1. Mabberley (1997) suggested that where the history of a particular cultivar is not certain it may be preferable to not use a Linnaean classification, and, for example in the case of the ‘Meyer’ lemon, refer to it as *Citrus* ‘Meyer’. Where there is certainty he considered it more informative to use a Linnaean system, where species and hybrid names for citrus crops indicate their presumed relationship with wild plants. The oldest name for the hybrid group involving oranges (pomelo-mandarin crosses) is *C. × aurantium* L. and that for the wild tangerine (i.e., mandarin) is *C. reticulata* Blanco, so that a Valencia orange is classified as *C. × aurantium* L. ‘Valencia’ and ‘Dancy’ tangerine is classified as *C. reticulata* Blanco ‘Dancy’.

Table 1. Specific and common names of 23 species considered to be true species of the genus *Citrus* (Rutaceae: Aurantioideae: Aurantieae) and their endemic region(s). Widely cultivated species are in bold.

Species	Common names	Endemic region
<i>C. amblycarpa</i> (Hassk.) Ochse (a possible hybrid)	sambal, djerook leemo, nasnaran mandarin, ‘Celebes’ papeda	Malaysia & Indonesia
<i>C. australis</i> (Mudie) Planch.	Australian round lime, dooja	Australia
<i>C. australasica</i> F. Muell.	Australian finger-lime	Australia

¹⁰⁰ Unless stated otherwise, classification of plants is based on Mabberley (1997, 1998, 2004, 2008), Scott et al. (2000), Samuel et al. (2001) and Bayer et al. (2009).

<i>C. cavaleriei</i> H. Léveillé ex Cavalerie (<i>C. ichangensis</i> Swingle)	Ichang papeda/lime/lemon	China
<i>C. garrawayi</i> F. M. Bailey	Mount White lime, Garraway's Australian wild lime	Australia
<i>C. glauca</i> (Lindl.) Burkill	Australian desert lime	Australia
<i>C. gracilis</i> Mabb.	Humpty Doo lime	Australia
<i>C. halimii</i> BC Stone	sultan lemon, limau kadangsa, limau kedut kera	West Malaysia & Sumatera in Indonesia
<i>C. hystrix</i> DC. (<i>C. macroptera</i> Montrouz.)	kaffir lime, limau purut, limau hantu	Southeast Asia
<i>C. inodora</i> F. M. Bailey	Russell River lime, large-leaf Australian wild lime	Australia
<i>C. japonica</i> Thunb. syn. <i>Fortunella</i>	kumquat	China
<i>C. medica</i> L.	citron	possibly New Guinea
<i>C. maxima</i> (Burm.) Merr.	pomelo	Indo-China
<i>C. neocaledonica</i> Guill.	false orange, large-leaf oxanthera	New Caledonia
<i>C. oxanthera</i> Beauvisage	orange flower oxanthera	New Caledonia
<i>C. polyandra</i> Tanaka syn. <i>Clymenia</i>		New Ireland in Papua New Guinea
<i>C. reticulata</i> ¹⁰¹ Blanco	mandarin, tangerine, satsuma: includes <i>C. × suhuiensis</i> ¹⁰² Hort. ex Tanaka, known as Canton mandarin, shatangju, sz-wei-kom, som keo wan, siem, xiem, limau langkat	China
<i>C. sp. (Oxanthera fragrans</i> Montr.)	fragrant oxanthera	New Caledonia
<i>C. trifoliata</i> L. syn. <i>Poncirus</i>	trifoliolate orange	China
<i>C. undulata</i> Guill.		New Caledonia
<i>C. warburgiana</i> F. M. Bailey	Milne Bay lime, New Guinea wild lime	New Guinea
<i>C. wintersii</i> Mabb. syn. <i>Microcitrus papuana</i> H. F. Winters	Brown River finger lime	New Guinea

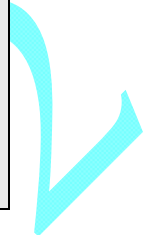
Table 2. Common hybrids within the genus *Citrus* (Rutaceae: Aurantioideae: Aurantieae) arranged in cultivated groups (see Zhang et al. 2008). Widely cultivated hybrids are in bold¹⁰³.

Hybrid	Common names
<i>C. × aurantiifolia</i> (Christm.) Swingle	lime
<i>C. × aurantium</i> L. (= <i>C. aurantium</i> L. and <i>C. sinensis</i> (L.) Osbeck)	sour, sweet, Valencia and navel oranges; grapefruit, and king orange/tangor/mandarin, the latter sometimes given as <i>C. nobilis</i> Lour.
<i>C. × indica</i> Tanaka	Indian wild orange
<i>C. × insitorum</i> Mabb. (× <i>Citroncirus webberi</i> J. Ingram & H. E. Moore)	citrangle
<i>C. × limon</i> (L.) Osbeck	lemon
<i>C. × macrophylla</i> Wester	alemow
<i>C. × microcarpa</i> Bunge	calamondin
<i>C. × taitensis</i> Risso (= × <i>jambhiri</i> Lush.)	rough lemon
<i>C. × latifolia</i> (Yu. Tanaka) Tanaka	Tahitian lime

¹⁰¹ Before 1930 most mandarins were referred to as *C. nobilis*.

¹⁰² This mandarin type, known in Guangdong as shatangju, is named after the town of Sihui, 63 km to the northwest, of Guangzhou in Guangdong China.

¹⁰³ Note the correct spelling of *aurantiifolia*.



wild allies, as revealed (Gibberley 2004).

sena

, which includes *M. panamensis* (Hemsl.) B. P. Burtt-Brown, is a member of the subtribe *Cladoclypeinae* and remains within the *Cladoclypeus* clade (Burtt-Brown et al. 2001) provided morphological characters of *Cladoclypeus caloxylon* (Ridley) Swingle and Molino (1994) led to the conclusion that *Cl. anisata* (Vahl) Burtt-Brown (Africa) is in fact native to the Americas (Burtt-Brown et al. 2001). There may be a single species (*Cl. anisata*), or two species (*Cl. anisata* and *Cl. exotica*), or two species (*Cl. anisata* and *Cl. exotica*) are uncertain (see Stone 1988). The two forms were reported by Burtt-Brown (1990) and Burtt-Brown et al. (2001). We consider the combination *Cl. anisata* (Vahl) Jack var. *exotica* (sensu Burtt-Brown et al. 2001).

in morphology and molecular biology (one resembling the other). (FM, pers. comm.). The former (1985).

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most of 'Ca. L. asiaticus'

Lopes et al. 2005, 2006) are related to an ornamental form (Silvio Lopes & Andrew Beattie, pers. discussions, December 2006). Most *Murraya* observed by one of us (GACB) with colleagues in Guangzhou, Guangdong, resemble the ornamental form, and plants sent from the Xishuangbana Botanic Gardens, Yunnan, China, and from the University of California, Riverside, California, to Indonesia for our studies resemble the ornamental form.



Figure 1. Forms of *M. paniculata* in HLB and *D. citri* susceptibility trials in Indonesia: the plant on the right resembles the common cultivated ornamental form.

We suspect that many host records for *D. citri* in China ascribed to *M. paniculata* (see Yang et al. 2006) are the ornamental form. There is an urgent need to resolve the status of *M. exotica* and, if it is a hybrid, its parentage, as the issue has important implications for management of HLB. Our prime concern is that under field conditions, one or both ‘forms’ may be an asymptomatic host of *Ca. L. asiaticus* either permanently after infection or temporarily. Nguyễn Huy Chung, an ACIAR John Allwright Fellow from the Plant Protection Research Institute in Hà Nội, is working to resolve these issues as part of his PhD at UWS.

Appendix II: Origins of Citrus

It is widely considered that *Citrus* originated in Southeast Asia between India and China and southwards through Malesia (Webber et al. 1967, Dugo & Di Giacomo 2002), but scant attention has been given by citrus horticulturists, pathologists and entomologists to the biogeography of *Citrus* and its close relatives since the impact of plate tectonics on the geography of the Earth were accepted in the 1960s and 1970s. The current perception of a Southeast Asian origin for *Citrus* is based on Swingle's¹⁰⁴ circumscription of the genus, as published in 1943 and 1967 (Swingle 1943, Swingle & Reece 1947), and widespread lack of awareness of the origins of both Southeast Asia and Australasia and how the landmasses are related. The eastern-most limit to the distribution of true species of *Citrus* is New Caledonia, which has been in the same relative position, some 1200 km east of Australia, for 55 mya: about the time that India collided with Asia (Hartley 2001a). The flora of New Caledonia contains many groups of plants that appear to be remnants of the late Cretaceous–early Tertiary (97 to 23 mya).

In commenting on the origins of *Microcitrus*, which they considered a primitive genus related to *Citrus*, Swingle & Reece (1967) opined that ‘these remarkable citrus fruits are extremely interesting, in that they show how evolution has proceeded in regions isolated as Australia and New Guinea have been during the last 20 or 30 my since they were cut off from all other landmasses’. Swingle & Reece 1967 also stated ‘perhaps some of its species are very like the ancestral species from which *Citrus* developed’ and ‘the evolution of other citrus fruits is not so easily followed, since *Citrus*, *Fortunella*, and *Poncirus* did not originate in regions that were geographically isolated in definitely dated geologic eras.’ They quoted Brough (1933), who in turn quoted Benson (1923), to support his view that ‘Australia is considered to have been joined to the Asiatic mainland at least during the Cretaceous period, but probably a complete separation has existed since the beginning of the Eocene.’ Swingle & Reece (1967) concluded that ‘The migrations of higher plants into Australia are held to have occurred during later Cretaceous times.’ The notion of the distribution of the Aurantioideae from Southeast Asia through Malesia to Australasia during the Neogene or Quaternary (up to 1.6 mya) periods, more recently than the Cretaceous era (146 to 65 mya), was considered likely as recently as the 1990s (Stace et al. 1993) in relation to movement of plants across ‘land-bridges’ (Armstrong 1975, Barlow 1981). Australia has never been joined to the Asiatic mainland (Hall 1997, 2001, 2002, van Welzen et al. 2005) and there is no record of species of *Citrus* being native to Wallacea, the islands between Wallace’s Line in the west and Lydekker’s Line, which runs along the Australasian continental shelf in the east.

Swingle’s view was that the genus *Citrus* may have originated in the New Guinea-Melanesia region (i.e., part of Australasia), and that it evolved into fragrant, delicious-flavoured species from a few species with sour and bitter-flavoured, almost inedible fruit, such as *C. hystrix* and *C. cavaleriei* (syn. *C. ichangensis*), that had developed in East Indian Archipelago, in the Philippines, New Guinea and Melanesia. He regarded this evolutionary path as the culmination of a very long period of progressive evolution that certainly began before Australia was cut off from land connection with New Guinea and Asia, probably more than 20 mya. He regarded the genera *Eremocitrus*, *Fortunella*, *Microcitrus* and *Poncirus* as ‘ancestral’ to his circumscription of *Citrus*. He regarded *C. polyandra* (syn. *Cly. polyandra*) as monospecific and probably the most primitive of all the genera within the ‘True Citrus Fruit Trees’, and with an extraordinarily close resemblance of leaves and petioles of those of *Monanthocitrus*, represented by the then monospecific *Monanthocitrus cornuta* (Lauterb.) Tanaka (there are now four described species of *Monanthocitrus*: see Stone & Jones (1988)). This convinced Swingle that *Cly. polyandra* was an entirely new type of citrus fruit tree, possibly having descended from a remote ancestral species common also to *Monanthocitrus*. He considered *Oxanthera*, which has large, white fragrant flowers very much like those of *Citrus*, to be

¹⁰⁴ Walter Tennyson Swingle 1871-1952.

a highly specialised xerophytic genus that possibly developed from the common ancestor of the genera *Wenzelia* and *Monanthocitrus*, and that the latter arose from an ancestral form much like that of some species of *Wenzelia*. He placed *Oxanthera*, *Wenzelia* and *Monanthocitrus* with several other 'minor citroid' genera in the subtribe Triphasiinae.

It is now clear that the species of *Oxanthera*, as species of *Citrus* (see Bayer et al. 2004, Bayer et al. 2009), belong to the true citrus group of fruit trees within the Swingle's subtribe Citrinae.

Moreover, Bayer et al. (2009) have shown that citron, *C. medica*, the first described species of *Citrus*, and long considered to be native to India, may have originated in Australasia, possibly in New Guinea. It and other Australasian species belong to a distinct Australasian clade that shares a common progenitor with Asiatic species that belong to a distinct Asiatic clade (Bayer et al. 2009). The closest relative of the citron is *C. polyandra*, a species native to New Ireland, a small island to the north-east of mainland Papua New Guinea (Bayer et al. 2009). Its next closest relatives are the *Citrus* species of New Caledonia, then the remaining Australasian species in Australia and New Guinea.

Most of the landmass Southeast Asia is derived from a complex agglomeration of terranes now far removed from their Gondwanan origins. North and South China (excluding Hainan and Taiwan), Indochina, Myanmar (Burma), Thailand, Malaysia and western Indonesia rifted from northeast Gondwana in three significant tectonic events starting in the Early Devonian (about 400 mya) and ending before the origin of Angiosperms (flowering plants) about 145 mya in the Early Cretaceous in the African component of Gondwana (Raven & Axelrod 1974, Burrett et al. 1991, Metcalf 1991, 1998, Scotese 1991, Crane et al. 1995, Morley 1998, Baillie et al. 2004, Burgoyne et al. 2005). The Rutaceae appeared in Africa-South America in the Mid Cretaceous, about 90 mya (Raven & Axelrod 1974). Muellner et al. (2007) estimated the age of Rutaceae as 91 my, the Aurantioideae as 71 my, *Citrus glauca* as 22 my, and *C. japonica* and *C. trifoliata* at 18 my.

Australasia comprises Australia (including Tasmania), New Guinea, the Bismarck Archipelago Solomon Islands, New Hebrides, Fiji, Lau, Tonga, Kermadec Islands, New Caledonia and New Zealand. Progressive separation of the now western margins of this region from India from 96 mya in the Late Cretaceous to 35.5 mya in the Late Eocene marked the second major phase in the breakup of eastern Gondwana. Separation of Madagascar from India, Australia from Antarctica, and New Zealand and New Caledonia from Australia also began about 96 mya in the Late Cretaceous. Separation of Australia and Antarctica ended when sea formed between the Tasmania (then still linked to the Australian landmass) and Antarctica about 35.5 mya (Hartley 2001a, b). India rifted northwards to collide with Asia in the Middle Eocene about 50 to 55 mya. At this point, both the northern margin of the Indian plate and Sundaland (Java, Sumatra, Borneo, western Celebes, Malaya, Shan and peninsular Myanmar, Thailand and Indochina) experienced an ever-wet, equatorial climate (Morley 1998).

Southern New Guinea is part of the Australasian craton whereas the northern sector comprises accretions of terranes of Pacific and Gondwanan origins, the latter including terranes that rifted into the Pacific and then back (e.g., New Britain and New Ireland). The terranes that form Wallacea originated from parts of Australasia, Gondwanic and Pacific accretions, and volcanoes following the collision of Australasia with Sundaland in the Middle Miocene (16 to 11.6 mya). These events over the past 55 million years have been most recently summarised by several authors (Veevers et al. 1991, Metcalfe 1998, Hall 1997, 2001, 2002, Hartley 2001a, b). Animations of events over the past 55 my can be viewed on the internet (SE Asia Research Group 2006:

- http://searg.rhul.ac.uk/current_research/plate_tectonics/globe_2001_svga.mov).

Other animations can be viewed at:

- <http://www.pbs.org/wgbh/nova/eden/media/sttnq.html>, and <http://kartoweb.itc.nl/gondwana/gondwana.html>.

These animations and detailed documentation of reconstructions (Hall 2001a, 2002) suggest that favourable opportunities existed for migration of *Citrus* from eastern Australasia to Asia via island arcs in the Pacific Ocean from the Bartonian (40.4 to 37.2 mya) stage of the Middle Eocene epoch (48.6 to 37.2 mya) until the present age, and likewise, but less likely given the movement of terranes and directions of flow of equatorial currents, for migration from Asia to Australasia.

Based on recent molecular evidence (Muellner et al. 2007, Bayer et al. 2009) that strongly support Asiatic origins of the genus, Beattie et al. (2006) hypothesised that the genus evolved in Gondwana. They (Beattie et al. 2008a, b) subsequently, hypothesised that the genus evolved in Australasia, and as Australasia rafted northwards and fragmented (Hall 1997, 2001, 2002) after separation from Antarctica. **This hypothesis forms the basis of our views on the origins of huanglongbing and several conclusions reached in this IMP.**

Fruit of early species, which may have been thick-rinded and buoyant (such as the citron and the pomelo) and salt tolerant species growing in coastal river delts (such as the pomelo: see Groff 1927), may have dispersed westward in equatorial currents, to Southeast Asia, when such currents existed to the north of what is now New Guinea (Beattie et al. 2008). Dispersal may have also been linked to island terranes that moved 1000s of kilometres eastward across the same region (Hall 1997, 2001, 2002).

Some dispersal could have been endozoochorous, through migrations of birds and bats. Evidence to support this is scant, as there have been no detailed studies. Mature fruits of extant native Australasian *Citrus* are relatively small compared to most extant cultivated Asiatic forms. Mature fruit of native Australian rainforest species are green. This suggests that their seeds may be dispersed by palaeotropical, non-echolocating, frugivorous, pteropodid bats; birds are more closely linked to dispersal of brightly coloured red and orange fruit (Hodgkison et al. 2003, Ingle 2003). However, mature fruits of extant citrus relatives native to New Guinea range from green to orange and red: *Mo. cornuta* fruit are small and red, and those of *Wenzelia dolichophylla* (Lauterb. & K. Schum.) Tanaka are red (Swingle & Reece 1967). Such endozoochorous dispersal if it occurred would have been aided by formation, movement and accretion of terranes to the east, north and west of New Guinea over the past 37 my (see Burrett et al. 1991; Hall, 2001a, 2002), particularly terranes that now form the Halmahera Islands and most of the Philippines (see Hall 2001a, b; Morley 2003). Evidence to support possible endozoochorous dispersal of primitive *Citrus* germplasm with relatively small fruit is provided by Hartley (2001a) in his treatise on the taxonomy, origins and biogeography of the Australasian genera *Euodia* and *Melicope*. Evidence of dispersal of sour and sweet oranges by water and animals is provided by Gade (1976) who noted that the distribution of these fruit in Paraguay was related to 'dissemination of the abundant propagules to uncultivated sites is achieved via the gaudy and bouyant fruit by birds, mammals, water and man' and that 'orange tree populations in remote forest areas may be attributed more to zoochory than anthropochory'. Parrots, attracted to brightly-coloured ripe fruit, carry orange pulp in their beaks, dropping pips along the way, and certain macaws, are fruit eating species. Mammal dispersers of seeds include monkeys, rodents, cattle and pigs (Gade 1976). Gade (1976) also mentioned that 'birds and mammals may disgorge or excrete viable seeds as their germinability is enhanced by gastric juices acting on the tough and woody seed coat'.

Appendix III. Origins of huanglongbing

The accepted view, as expressed by Zhao (1981), da Graça (1991), Bové (2006), and in many other publications, is that that HLB¹⁰⁵ originated in China. It is based on three assumptions: (a) that the disease was present in China in the 1800s (Lin 1956), (b) that Reinking (1919), Lee (1921), Tu (1932), and some other authors, described symptoms of the disease, and (c) that HLB evolved with *Citrus*. However, presence of the disease in China in the 1800s was based on interviews with farmers and technicians between 1947 and 1955 (Lin 1956), and the symptoms of maladies described by Reinking (1919) and Lee (1921) do not describe HLB. Furthermore, there is no evidence that HLB evolved with *Citrus*. Wallace (1978), in reviewing leaf-mottle yellows disease in the Philippines, concluded that the ‘mottle leaf’ studied by Lee (1921), was caused by Zn deficiency and the severity of leaf mottle on trees on pomelo was due to the susceptibility of the stock to CTV. Reinking (1921), in his report on ‘Citrus diseases of the Philippines, Southern China, Indo-China and Siam’, did not mention symptoms akin to those of HLB.

Early Indian records of symptoms resembling those of the disease seem to have been ignored. These records suggest that symptoms resembling those of HLB in *Citrus* were reported in the mid 1700s in the central provinces of India by Roghoji, the Bhonsla Raja of Nagpur (Capoor 1963). Other reports suggest that the disease was present in north-western and north-eastern India in the 1800s and early 1900s (Bonavia 1888-1890, Husain & Nath 1927, Pruthi & Mani 1945, Asana 1958, Capoor 1963, Fraser et al. 1966, Chadra et al. 1970, Raychaudhuri et al. 1972).

Husain & Nath (1927), when describing severe damage by *D. citri* populations at Sargodha in the western Punjab between 1915 and 1920, were the first, in a widely overlooked paper, to describe damage resembling that caused by HLB. In part they said: ‘... *D. citri* neither produces galls nor causes any malformation of the plant tissues. The only sign of injury is defoliation and death of the shoots attacked and the drying up of the branches. On badly infested trees the continual feeding of myriads of insects is, in itself, a very great drain on the food-supply of the plant, but most probably some poison is also injected into tissues of the host and this produces the more serious results. This is evident from the fact that the fruit of the infested tree is dry and insipid to taste, and branches other than those actually attacked also dry up. Besides, young shoots are killed, old leaves fall off and in course of time an attacked tree is denuded of leaves altogether’ ‘During the second year of attack, if the pest has been allowed to develop unchecked, all the new shoots are destroyed, and most of the branches are left without leaves and the tree begins to dry up. Very little fruit is borne and that too is of small size, insipid and dry.’ They noted that ‘The symptoms of attack by the nymphs of the citrus psylla consists in the malformation of leaves which are badly curled, look sickly and fall off prematurely’.

With the benefit of current knowledge, it is clear that the severe symptoms described by Husain & Nath (1927), and later by Pruthi & Mani (1945), were symptoms now known to be caused by ‘*Ca. L. asiaticus*’. Damage caused by *D. citri* is much more benign and does not lead to death of trees.

Fraser (1966) commented on the citrus industry in India before and after partition in 1947 from Pakistan. Most of the industry was confined to a band extending southwest from Assam and West Bengal in the east through central India around Nagpur in Mararashtra State to the state of Madras (now Chennai) in the southeast and Mysore and Kerala in the southwest (Fraser 1966). Fraser (1966) noted that;

- HLB was not present in Assam and West Bengal in the 1940s;
- in Mararashtra, a 48 year-old mandarin planting that she observed must have predated the introduction of HLB into the area;

¹⁰⁵ Huanglongbing is the official name of a disease of *Citrus* and other Rutaceae caused by ‘*Ca. L. americanus*’, ‘*Ca. africanus*’ and ‘*Ca. L. asiaticus*’ (Moreno et al. 1996, van Vuuren 1996). It should not be called citrus huanglongbing. Recent use of huanglongbing in relation to ‘*Ca. L. psyllaurosus*’ (Hansen et al. 2008) in tomato and potato is invalid and misleading.

- sudden wilting that she thought was due to HLB may have occurred at Poona in Maharashtra in 1946;
- the first commercial citrus trees planted at Kalimpong in West Bengal in 1864 lived for 50-60 years; and
- that a major extension of plantings in Assam commenced in 1927-1929, but there were no reports of dieback (HLB) before 1947-48, although there was a reference to some chlorosis in 1940-1941 in one area.

The citrus industries of Pakistan and India underwent considerable expansion in the 1930s and 1940s (Fraser 1969). A further expansion in the (eastern) Punjab followed partition, when citrus growers from Pakistan were encouraged to plant large acreages, particularly of sweet oranges, in newly opened irrigation settlements¹⁰⁶. The spread of dieback (HLB) coincided with this expansion and the use of infected planting material (Fraser 1966).

Aubert (1990a) considered movement of citrus material as the most efficient way of disseminating HLB and *D. citri*. His view (Aubert 1990a) was that they had been introduced unwittingly into many countries in Southeast Asia after 1940, particularly by nurserymen, orchardists and home gardeners replacing traditional local varieties.

With the possible exception of China, HLB symptoms were not recorded in Southeast Asia until after 1940: in Indonesia in the 1940s, where its importance was noted as early as 1948 (Aubert et al. 1985), in Taiwan before 1951 when it was recorded as serious (Su & Huang 1990), in the Philippines in 1957 (Martinez & Wallace 1967), Thailand in the 1960s (Schwarz et al. 1973ab, Aubert 1990c), and in Malaysia in the 1970s (Ko 1988, 1991) where its presence was confirmed in 1989 (Lim et al. 1990a). Human-assisted spread of the disease through the Indonesia archipelago (Tirtawidjaja 1980) to Papua New Guinea (northern Australasia) (Davis et al. 2000, Weinert et al. 2004) took more than 50 years.

Recently observed records from Indonesia indicate that citrus was introduced from China on 2-3 occasions to the Bogor Botanic Gardens in 1945 (Inggit Puji Astuti, Bogor Botanic Gardens, pers. comm., 25 January 2008). This was around the time that the disease became widespread and severe in Guangdong (Lin 1956) and 11 years after Zhou Yuwen¹⁰⁷ recorded *D. citri* in Guangdong (Hoffmann 1936). The origin of HLB in the Philippines is not known¹⁰⁸. However, there were many introductions of budwood and small budded trees from mainland China, India, Japan and Taiwan before 1957 (Martinez & Wallace 1969). Information provided by Ko (1991) and Saamin et al. (1991) suggests that the first record of the disease in Peninsular Malaysia may have been related to the introduction of *C. reticulata* seedlings (in this instance Tanaka's *C. suhuiensis*, a mandarin variety from Sihui near Guangzhou in Guangdong) to Terengganu from China in the 1950s and 1960s.

It is highly likely that the disease was not widespread in China before the 1940s and that it may not have occurred there before 1930:

- the first authentic record of the disease appears to have been made by Chen Qibao in 1938 (Chen 1943, Lin 1956), four years after Zhou Yuwen collected *D. citri* on citrus and other hosts at Lingnan University in Guangzhou (see Hoffmann 1936);
- parasitoids were not associated with these psyllid populations (Hoffmann 1936);

¹⁰⁶ Extensive irrigation systems were constructed in the western Punjab, of Pakistan, between 1885 and 1947 (Ali 1988)

¹⁰⁷ Zhou (Djou) Yuwen became a professor of entomology at Zhongshan University on the original site of Lingnan University. In the 1940s he worked with John Lindsley Gressitt (Bishop Museum, Hawaii) and Stanley Ellsworth Flanders (University of California, Riverside) on parasitoids of red scale, *Aonidiella aurantii* (Maskell).

¹⁰⁸ The symptoms of 'mottle leaf' reported in the Philippines by Morada (1930) resemble nutrient deficiencies, and it is clear from his notes on the severity of the malady that it was not HLB.

- Condit et al. (1937) clearly and unequivocally linked major losses of trees to poorly drained lowland areas;
- Benemerito (1938) in his paper on oranges of Guangdong, in which he noted the dates of introductions of varieties from China to the Philippines, did not mention maladies consistent with HLB-like;
- reports on citrus cultivation by the Botanical and Forestry Department of Hong Kong from 1853 to 1941¹⁰⁹ do not mention records of *D. citri*, or any citrus maladies resembling HLB from 1924 to 1939; and
- Aubert (1990), in discussing Jiaogan (Tankan) tangor production in the Chaoyan district of Guangdong from 1946 and 1990, noted that the first dramatic HLB epidemic in the region occurred from the late 1950s following use of contaminated trees, and that subsequent epidemics were related to natural spread of the disease by *D. citri* (Aubert 1990).

Condit et al. (1937) noted: 'As stated by Tu the short life of the trees is undoubtedly largely due to the high water table, poor drainage, shallow roots and the subsequent failure of the root system to renew itself and to function properly. The fact that well drained and deeper soils adjacent to nearly all lowland orchards, citrus trees up to fifty years old are to be found still vigorous and productive in spite of insect borers and bark diseases, leads one to regard the soil moisture content as the principal factor contributing to the early decline of the lowland trees.' They attributed chlorosis, that considerably alarmed Ch'ao-an growers, to the inability of the leaf to get sufficient iron on sandy soils. They reported that 'mottle leaf' of rare occurrence, in contrast to Tu (1932) who considered 'mottle leaf' being worst in the Guangzhou delta region. 'The leaves may be sickly, pale green, or yellow, but seldom distinctly mottled. In fact the deep green color of the foliage in most orchards is remarkable, considering the soil conditions in which the roots are growing.'

Contrary to other reports they said that they wished 'to emphasize the fact again that trees of the sweet orange and of loose-skin oranges up to twenty-five or thirty years and of pummelo up to fifty years old are common in well drained soils. For this reason we doubt that bark diseases are so much 'the limiting factor' as poor drainage and the consequently restricted root system.' Condit et al. (1937).

These records suggest eastward movement, directly or indirectly, of the disease and the psyllid from the Indian subcontinent to Guangdong, and then to Taiwan, the Philippines, Thailand, Malaysia and Indonesia. The introduction to China appears to have occurred in the late 1920s or early 1930s and may have involved lemon and pomelo cultivars. In addition to movement of plants by nurserymen, orchardists and home gardeners, such introductions may have been linked to exploration for new species of plants.

Exploration for *Citrus* species and varieties, and *Citrus* relatives, in China, Việt Nam, Thailand and the Philippines was initiated by the eminent citrus taxonomist Walter Tennyson Swingle, who visited Lingnan University¹¹⁰ in 1916 and collaborated with staff there, and in the Philippines, over many years (Groff 1927, McClure 1931, Reinking 1921¹¹¹, Cooper 1989)¹¹². These plants appear to have been both grafted and ungrafted¹¹³. Some plants were introduced to the United States of America, most via the Philippines, so as to reduce the risk of new pests and diseases entering America (Groff 1927. Groff 1934). Records are still being obtained, and in the case of those written in Chinese, translated. Wang (1934) mentions '*Citrus magner* ex Hort.' (sic), a lemon type (*C. limonia* Osbeck var. nov. *wagner*), being introduced to Guangdong by George Groff from the garden of Mr Wagner, a French resident of Saigon (now Ho Chi Minh City). The introduction of plants from Saigon to China is also mentioned by Groff (1934) in the 1929-1934 records of the Economic Plant Receiving Station at Lingnan University. The station was established to reduce the

¹⁰⁹ Hong Kong Government Reports Online (1853-1941): <http://sunzi1.lib.hku.hk/hkgro/index.jsp>.

¹¹⁰ Now the location of Zhongshan Daxue (Zhongshan University): also called Sun Yat-Sen University.

¹¹¹ *Citrus* relatives from Africa were among plants introduced to the Philippines (Reinking 1921)

¹¹² Other foreign scientists involved in exploration and introductions during this period included George Weidman Groff, Franklin Post Metcalf, Floyd Alonzo McClure and Elmer Drew Merrill.

¹¹³ McClure's field notes, Zhongshan University herbarium, Guangzhou, photographed by GAC Beattie, 2007.

risk of pests and diseases into China, and the records mention introductions of several *Citrus* species and varieties to southern China from elsewhere in Southeast Asia. There is no direct evidence that these plants harboured HLB or *D. citri*, but there is a possibility their introduction to China may have led to the introduction, either directly or indirectly (e.g., from India, or India via Việt Nam), of both the disease and vector to China. Groff's (1934) records, and Hoffmann's account of the discovery of *D. citri* in Guangzhou suggests that it, and possibly '*Ca. L. asiaticus*', were introduced to Lingnan University on imported plants. Infested and infected plants may have occurred in Việt Nam, or elsewhere in Indo-China and the Malay Peninsular, but their presence may not have been noticed given that populations of major cities were relatively small. Moreover, citrus cultivation appears to have been low (below 500 ha?) in Việt Nam, and largely restricted to home gardens in rural areas¹¹⁴. Feldwick (1917) does not mention citrus cultivation in the Saigon region. Between 1860 and 1923 the population of Saigon grew from 6000 to 100,000. Growth thereafter was less dramatic: between 1921 and 1947 it increased 1.7 times (Guillaume 1985). Together with the nearby town of Cholon, the total population of Saigon-Cholon in 1917 was about 250,000 (Feldwick 1917).

The above records suggest that '*Ca. L. asiaticus*' may have originated in India, as also suggested by Halbert & Manjunath (2004). It is possible that it may have evolved there in association with asymptomatic forms of *M. paniculata*, *B. koenigii* or species of *Clausena*, but not species of *Citrus*, as recent studies by Bayer et al. (2009) suggest that no true species of *Citrus* are native to India. However, the authors of this IMP consider sub-Saharan Africa to be the most likely origin of the '*Ca. Liberibacter*' forms that cause HLB.

The African form of HLB was first reported (as Transvaal citrus greening) in Rustenberg in Western Transvaal (now Northern Province) in South Africa in about 1928-29 (predating our views on when it first occurred in China) and was spread to other areas with infected planting material (van der Merwe & Andersen 1937, Oberholzer et al. 1965, Moll 1977)¹¹⁵. It is characterised by chlorotic leaf symptoms, as well as poor crops of undersized and poorly coloured fruit of inferior quality. It caused severe crop losses in the Eastern Transvaal (now Mpumalanga) during the periods 1932-36 and 1939-46, but was of little importance elsewhere. From 1958, severe crop losses occurred in the Eastern and Western Transvaal and greening spread elsewhere in South Africa, presumably due to the upsurge of *T. erytrae* as a serious pest in citrus orchards particularly, in cooler areas > 700 m asl, where humidity rarely falls below 25% and mean monthly maximum temperatures vary between 18°C and 30°C (Oberholzer et al. 1965, Buitendag & von Broembsen 1993). Previously, *T. erytrae* had been troublesome only in nurseries (Buitendag & von Broembsen 1993). When a few HLB affected trees (with their origins in the north) were found in the Eastern and Western Cape in the 1960s, they were destroyed and restrictions were placed on the movement of planting material from greening infected provinces. In 1995, the disease was detected in an isolated spot in the Eastern Cape and trees were eradicated. At this point it was also recorded at Stellenbosch in the Western Cape, where the disease continues to spread slowly (le Roux 2006).

Africa is the only region in which a common association between a HLB pathogen and a seemingly asymptomatic and preferred host of a vector appears to occur: in an association involving *T. erytrae* and *V. lanceolata*. Moran (1968) suggested that *V. lanceolata*, *Cl. anisata* and *Z. capense* could be the original native hosts of *T. erytrae* in Africa, but *Cl. anisata* is not native to Africa (Molino 1994) and *Z. capense* is a relatively poor host. da Graça (1991) mentioned that efforts (JV da Graça & SP van Vuuren unpublished data) to transmit the African form of the disease to *V. lanceolata*, *Cl. anisata* and *Z. capense* by *T. erytrae* were unsuccessful, but he did not mention how the tests were done, or whether there was an expectation that the plants would exhibit

¹¹⁴ In 1991 the total area in Việt Nam was about 5,000 ha (Whittle 1992).

¹¹⁵ These reports coincide with the first records of *T. erytrae* being recorded as a pest of citrus in South Africa: albeit with damage caused directly by the pest, not HLB: see, van der Merwe (1923).

symptoms of the disease as normally observed on *Citrus*. However, subsequent studies indicate that *Cl. anisata* and *V. lanceolata* can harbour the bacterium. van den Berg et al. (1991-1992, 1992b) reported detection of the pathogen from psyllid infested *Cl. anisata* growing in close proximity to a HLB-infected citrus orchard. Detection was based on tests involving grafting of sweet orange indicator plants to the *Cl. anisata* trees. Simultaneous tests with the native *V. lanceolata* and *Z. capense* were negative (van den Berg et al. 1991-1992), but Korsten et al. (1996), using dot blot hybridisation, detected the bacterium in a leaf sample taken from a *V. lanceolata* tree on which many *T. erytrae*-induced leaf deformations were observed. van den Berg et al. (1991-1992) recommended removal of *Cl. anisata* plants growing near citrus orchards and Korsten et al. (1996) concluded that *V. lanceolata* is a reservoir plant for the pathogen. van den Berg et al. (1991-1992, 1992) and Korsten et al. (1996) did not mention the presence of HLB symptoms in any of these non-*Citrus* hosts of *T. erytrae*, and there are no reports of dieback or death of trees.

It is highly unlikely that HLB originated in Asia or Australasia in association with *Citrus* or any *Citrus* relative. There would be a high probability that any such association would lead to rapid extinction of the host plant(s) and the bacterium. Moreover, HLB does not occur naturally in Australasia and no indigenous psyllids species have been recorded feeding on indigenous species of *Citrus*.

In 2006, we considered it possible that the three currently recognised '*Candidatus Liberibacter*' 'species'¹¹⁶ ('*Ca. L. asiaticus*', '*Ca. L. africanus*' and '*Ca. L. americanus*') and the one 'sub-species' ('*Ca. L. africanus* subsp. *capensis*') that cause HLB (da Graça & Korsten 2004; Teixeira et al. 2005a, b), may represented forms of a single 'species' that had adapted to new hosts and environments in the recent past (perhaps < 500 years) (Beattie et al. 2006). Our opinions differed about the validity of the three 'species' of '*Ca. Liberibacter*' and we were concerned that the bacteria may have the capacity to adapt rapidly to new hosts and environments (Beattie et al. 2006). We reasoned that the probability of three forms evolving on more than one continent after the separation of Gondwana, and in an initial association with a single, most probably asymptomatic, host plant species and with a single psyllid vector, would be negligible.

Based on this evidence and movement of plants by humans, we consider it possible that HLB was transmitted from *V. lanceolata* to orange or mandarin trees by *T. erytrae* in one of the European colonies on the southeast coast of Africa and then taken to the Indian subcontinent in infected plants or budwood some 300-500 years ago. It could then have been acquired and spread by *D. citri*. Spread could also have occurred through marcotting (air-layering) and grafting, and enhanced by changes in horticultural practices, that through increased use of irrigation and fertilisers within monocultures, would have led to more abundant and frequent growth flushes. The latter would have led to far higher populations of *D. citri* than would have occurred in its original environment. Aubert (1988a) commented that although widely distributed throughout the Orient, *D. citri* has a relatively narrow habitat restricted to *Citrus*, *M. paniculata* and two rare *Clausena* spp., and that *D. citri*, unlike *T. erytrae*, is not able to build up massively on a wide range of alternative rutaceous forest trees or shrubs. He suggested this as a reason why '*Ca. L. asiaticus*' in Asia is generally far more associated to man's activity in densely populated areas than '*Ca. L. africanus*' in Africa. He (Aubert 1988a) considered *D. citri* to be an ecologically opportunistic insect that dispersed 'along the main communication tracks' of naturally occurring and cultivated '*Citrus* and *Murraya paniculata*'.

Our views on the origins of the nominal genus '*Candidatus Liberibacter*' are being reconsidered in light of recent reports (e.g., Liefting et al. 2008a,b) of a fourth 'species' of '*Ca. Liberibacter*' being discovered in potato (*Solanum tuberosum* L.), tomato (*S. lycopersicum* L.) [Solanales: Solanaceae]

¹¹⁶ 'It is important to note that the category *Candidatus* is not covered by the Rules of the Bacteriological Code. Consequently, a name included in the category *Candidatus* cannot be validly published, and it also cannot be designated sp. nov., gen. nov., etc.'; Euzéby JP. 2008. List of Prokaryotic names with standing in nomenclature. <http://www.bacterio.cict.fr/candidatus.html>.

and other solanaceous plants in New Zealand (Liefting et al. 2008a,b) in association with the recently introduced potato/tomato psyllid *Bactericera* (= *Paratrioza*) *cockerelli* (Šulc) [Psyllidae], presumably from North and/or Central America¹¹⁷, and reports of possibly the same pathogen being detected in tomato and potato in California (Hansen et al. 2008). These are the first report of the pathogens occurring naturally in plants other than species of Rutaceae, and it is uncertain as to when symptoms caused by the pathogen in the Solanaceae were first noticed in the Americas prior to the report of Hansen et al. (2008). Hansen (2008) noted that the most similar 16S rRNA sequence to the new '*Ca. Liberibacter*' species is sequence DQ471901 '*Ca. L. asiaticus*' from Brazil: they did not mention it in relation to '*Ca. L. americanus*'.

Solanales are estimated to be from the mid-Cretaceous (Bremer et al. 2004) (about 97 mya) and Muellner et al. (2007) estimated the age of the Rutaceae to be late Cretaceous (91 mya) and the Aurantioideae later in the same period (71 mya).

Eveillard et al. (2008), in an estimation of 'speciation' dating, considered '*Ca. L. asiaticus*' and '*Ca. L. africanus*' diverged some 150 million years ago, while speciation of '*Ca. L. americanus*' might have started some 300 million years ago. Doddapaneni et al. (2008b) considered that speciation may have occurred 110-120 mya, before the breakup of Gondwana. Teixeira et al. (2008) estimated that '*Ca. L. africanus* and *Ca. L. asiaticus*' diverged 147 mya and that the splitting between '*Ca. L. americanus*' and the '*asiaticus/africanus*' branch would have occurred 309 mya. At the family level, psyllids appear to have colonised relatively few major lineages of plants during the diversification of both angiosperms and psyllids in the Cretaceous (146-65 mya), and subsequently evolved and diversified with their hosts (Hodkinson 1984). Gullan & Martin (2003) noted that the fossil record of the Psylloidea extends back to the Permian (> 270 mya). The extant families probably diversified in the Cretaceous (Gullan & Martin 2003). However, there is no evidence that '*Ca. L. americanus*' occurs naturally in the Americas: the only known hosts are not native to the Americas. Furthermore, there appears to be no logical reason, given the paucity of native species of Rutaceae and psyllids in South America, to support notions that the disease, in any form, evolved in Rutaceae in South America. Both '*Ca. L. americanus*' and '*Ca. asiaticus*' were discovered at the same location in two orchards in São Paulo State in Brazil, and are spreading from that point (Silvio Lopes, pers. comm, September 2008, Lopes 2008,). Since discovery of the disease in São Paulo State in 2004, '*Ca. L. americanus*' has been the most prevalent species in citrus (Gottwald et al. 2007), and it appears to have had sufficient time to move freely from citrus to orange jasmine, without any of the limitations provided by removal of symptomatic trees or applications of insecticides, practices currently adopted in the management of HLB in citrus orchards (Lopes et al. 2008 in press). However, in the past 4 years, a disproportional increase in '*Ca. L. asiaticus*' incidence has been observed in citrus orchards. Both forms were introduced simultaneously in the mid 1990s to Brazil, where *D. citri* has been present since about 1940 (Halbert & Núñez 2004).

If the bacteria evolved before the breakup of Gondwana, then their widespread distribution in Africa, Asia and South America can be explained by vicariance. The difficulty with this interpretation is the date of origin of plants in which the organisms are known to occur. To accommodate the age estimates of Eveillard et al. (2008) and Doddapaneni et al. (2008b) it will be necessary to identify hosts that may have occurred up to 300 mya, when only Gymnosperms were present, and how the bacteria moved from plant to plant. Currently, the bacteria are only known to colonise two families of Angiosperms, the Rutaceae, within the subfamilies Rutoideae and Aurantioideae, and the Solanaceae. The putative oldest member of '*Ca. Liberibacter*', '*Ca. L. americanus*' has only been detected in two Aurantieae genera (*Citrus* and *Murraya*), and no genera within this tribe, or in the Clauseneae, the other recognised tribe within the Aurantioideae, are indigenous to the South America. '*Ca. L. asiaticus*' has only been detected in the Aurantioideae. '*Ca. L. africanus*' has only been found naturally within African Rutoideae, and the Rutoideae

¹¹⁷ See: <http://www.biosecurity.govt.nz/pests-diseases/plants/potato-tomato-psyllid.htm>.

evolved before the Aurantioideae (Bayer et al. 2009) and occur naturally in all continents aside from Antarctica.

A brief summary, based on literature referred to above, and some other sources, of our interpretation of events related to the evolution of Rutaceae, Solanaceae, psyllids and liberibacters, and the spread of HLB into *Citrus* is presented in Table 1.

Table 1. Summary of presumed historical events related to the evolution of Rutaceae, Solanaceae, psyllids and liberibacters, and the spread of HLB into *Citrus*, assuming Solanales originated in the Mid Cretaceous (see Bremer et al 2004) and Rutaceae from 91 mya (see Mueller et al. 2007). Dates are based on Holloway & Hall (1998).

Tectonics & Flora	Era	Period	Epoch	Start of each period (mya)	Fauna & bacteria
Extant Rutaceae and Solanaceae. Movement of plants by humans. Citrus monocultures from 1800s.	Current			0.002	Three 'Ca. Liberibacter' transmitted from their natural asymptomatic hosts to symptomatic <i>Citrus</i> and <i>Citrus</i> relatives, independently on three continents; only one form, 'Ca. L. africanus' with a possible natural host and a possible natural vector; 'Ca. L. asiaticus' with a possible natural vector but no identified natural asymptomatic host; 'Ca. L. americanus' with no identified natural host or vector. First encounters of <i>D. citri</i> and <i>T. erytrae</i> with <i>Citrus</i> . No beneficial or detrimental impacts of 'Ca. Liberibacter' on vectors demonstrated. Psyllid vectors move from natural hosts to colonise citrus monocultures.
Ongoing evolution of <i>Citrus</i> ?	Cenozoic	Quaternary	Holocene	0.1	'Ca. Liberibacter' exist in unknown hosts and with no identified insect vector(s)?
Ongoing evolution of <i>Citrus</i> ?			Pleistocene	1.6	
<i>Citrus japonica</i> (18 mya) <i>Citrus trifoliata</i> (18 mya) <i>Citrus glauca</i> (22 mya) Speciation of <i>Citrus</i> continues in Australasia and in Asia, in the absence of 'Ca. Liberibacter' and psyllids that feed on citrus.		Tertiary	Pliocene	5	
<i>Citrus medica</i> (?? mya) <i>Citrus progenitor</i> (?? mya). <i>Citrus</i> evolves in Australasia in the absence of 'Ca. Liberibacter' and psyllids that feed on citrus.			Miocene	23	
			Oligocene	35	
			Eocene	57	
			Paleocene	65	
	Mesozoic	Cretaceous	Late	97	'Ca. Liberibacter' present in asymptomatic Rutaceae, initially Rutoideae?; and/or Solanaceae? Geographic separation of 'Ca. Liberibacter' complete?
Aurantioideae (71 mya): Clauseneae (to comprise now extant <i>Berberis</i> , <i>Clausena</i> , <i>Micromelum</i> & <i>Glycosmis</i> in Asia & Australasia) evolve before Aurantieae (initially <i>Murraya sensu stricto</i> , in South and Southeast Asia, finally <i>Citrus</i> in the Oligocene?).					Evolution of psyllids on Rutoideae then Aurantioideae?

Rutoideae (91 mya) Rutaceae (91 mya)					
Breakup of East Gondwana begins (110- 120 mya) <i>Cuscuta</i> progenitor Solanales			Early	146	Ongoing speciation of ' <i>Ca. Liberibacter</i> ' Diversification of psyllids (146 mya)
		Jurassic	Late	157	
Geographic separation of ' <i>Ca. Liberibacter</i> ' commences? Breakup of East and West Gondwana commences 167 mya Angiosperms (180-140 mya)			Middle	178	
			Early	208	
		Triassic	Late	235	
			Middle	241	
			Early	245	
	Paleozoic	Permian	Late	256	
			Early	290	Psyllid progenitor (> 270 mya)
		Carboniferous	Late	322	Sternorrhyncha ('Homopteran') progenitor (300 mya); speciation of ' <i>Ca. L. americanus</i> ' (300 mya)
			Early	363	
Gymnosperms (365 mya)		Devonian	Late	377	
			Middle	386	
Ferns (390 mya)			Early	409	Phytophagous insects (390 mya)
		Silurian	Late	424	
Vascular plants (425 mya)			Early	439	
		Ordovician	Late	476	
			Middle	510	
			Early	517	
		Cambrian	Late	536	Arthropods (525 mya)
			Early	570	
	Precambrian	Proterozoic		2500	
		Archaean			

We cannot gauge the accuracy of the age estimates of Eveillard et al. (2008) and Doddapaneni et al. (2008b). However, we still wonder whether diversification of the bacteria occurred more recently than their estimates, even, as Beattie et al. (2006) hypothesised, in the past 1,000 years? Is it possible that modern agricultural practices may have led to relatively rapid adaptations to new hosts and environments? Geographical variation in '*Ca. L. asiaticus*' has been reported in regions where the pathogen does not occur naturally (e.g., Garnier et al. 1991, Gao et al. 1993, Bastianel et al. 2005, Teixeira et al. 2005c, Subandiyah et al. 2006, Doddapaneni et al. 2008a, Zhou et al. 2008a), and severe symptoms have been reported in hosts, e.g., limes and pomeloes, that until recently have been considered tolerant (Susan Halbert, Florida Department of Agriculture and Consumer Services, pers. comm, 2008, and Dent et al. 2008). Is it possible, if the phylogenetic relationships derived by Bastianel et al. (2005) and Teixeira et al. (2005c), and the age estimates of Eveillard et al. (2008) and Doddapaneni et al. (2008b), are accurate, that all three forms of '*Ca. Liberibacter*' that cause HLB originated on one continent, Africa, and that two of the forms have spread anthropogenically from there?

With the possible exception of *V. lanceolata* no asymptomatic hosts have been identified, nor have insect vector-associations with these plants and plants in which the pathogens cause disease been identified. In the absence of psyllid vectors and possible seed transmission, the only avenues we can suggest for natural spread from plant to plant are root grafts and transmission by parasitic plants, particularly *Cuscuta* spp [Solanales: Convolvulaceae].

Halbert & Manjunath (2004) considered natural transmission of HLB by *Cuscuta* spp. unlikely. However, there is a possibility that natural and anthropogenic dispersal of species such *Cu. australis* and *Cu. campestris* may have contributed to the spread of several pathogens known to be transmitted by them, including HLB. Dodder is common parasite of a broad range of plants in Asia (Browne 1968, Rajak et al. 1985, Abu-Irmaileh 1987, Abu-Irmaileh & Fucik 1989, Banerjee et al. 1993). Seeds can persist in soil, and are often planted with contaminated seed of other plants (O'Driscoll 2003). Some species of *Cuscuta* have very broad host ranges, and host can vary from cereals, lucerne, clover, herbs, vegetables (e.g., carrot, celery, potato, capsicum and eggplant), flax, linseed, shrubs, and trees (Knorr 1949, Rajak et al. 1985, Abu-Irmaileh 1987, Abu-Irmaileh & Fucik 1989, Banerjee et al. 1993, O'Driscoll 2003, Stefanović et al. 2007).

The genus *Cuscuta* evolved before the breakup of Gondwana and diversified in South and Central America (Stefanović et al. 2007). The genus comprises some 165–175 currently described species¹¹⁸. It is nearly cosmopolitan in distribution with species found on every continent (except Antarctica), ranging from 60° N to 47° S (Stefanović et al. 2007). The vast majority of species of *Cuscuta* only occur in the Americas with Mexico and adjacent regions as a centre of diversity. Despite their wide cosmopolitan distributions, *Cu. australis* and *Cu. campestris* (one of the most successful parasitic weeds), are of North American origin.¹¹⁹

Rutaceous hosts of dodder in laboratory and field observations include *Citrus* species and hybrids (Abu-Irmaileh 1987, Abu-Irmaileh & Fucik 1989, Byadgi & Ahlawat 1995, Ahlawat et al. 1996, Pant & Ahlawat 1998), bael (*Aegle marmelos* (L.) Corr. [Aurantieae] (Rajak 1985), and toothpick glycosmis (*Glycosmis trifoliata* (Blume) Spreng. syn. *Glycosmis pentaphylla* (Retz.) DC. [Clauseneae]) (Banerjee et al. 1993).

HLB and pathogens of citrus other than those that cause HLB can be transmitted by dodder. Species of *Cuscuta* have been used to transfer liberibacters between hosts (Tirtawidjaja 1981, Garnier & Bové 1983, Ke et al. 1988, Olfato et al. 1990, 1991, Subandiyah 1994, Duan et al. 2008 Zhou et al. 2007). 'Ca. L. asiaticus' can multiply and spread within infected *Cu. ceanothi* Behr (syn. *Cu. subinclusa* Dur. & Hilg.), *Cu. campestris*¹²⁰ (Ghosh et al. 1977) and *Cu. australis* (Su & Huang 1990)¹²¹. Ghosh et al. (1977) observed that the pathogen multiplied more favourably in dodder on diseased sweet orange (which they assumed to be natural host of the pathogen) and suggested this as evidence that it could be possible to use dodder as an alternative host of the pathogen. Zhou (2008) reported that infected *Cu. pentagona* plants did not exhibit symptoms of HLB even when they contained high titres of 'Ca. L. asiaticus'. Other diseases transmissible by dodder include transmission by *Cu. reflexa* Roxb. in India of citrus yellow corky vein (Reddy & Naidu 1989), a viral ringspot disease of citrus (Byadgi & Ahlawat 1995), and a badnavirus associated with citrus mosaic disease (Ahlawat et al. 1996).

¹¹⁸ All members of the genus are vines with twining, slender, pale stems, with reduced, scale-like leaves, and no roots. They become attached to stems by haustoria and depend almost entirely on their hosts to supply water and nutrients (Stefanović et al. 2007). Most species have reduced amounts of, or no, chlorophyll (Stefanović et al. 2007). They divert sugars from the host crop, weakening plants and often causing total failure to set fruit.

¹¹⁹ The monophyletic nature of these species, nested within a clade with narrow distributional ranges, led Stefanović et al. (2007) to conclude that that their physiological capability to use hundreds of genera as hosts probably arose once, in their common ancestor. This capability thus allowed them to spread over large geographic areas, either naturally or as consequence of anthropogenic influences. Stefanović (et al. 2007) concluded that there was little doubt that the initial jump in dispersal and speciation had to occur from the Old World, most likely Africa, to the New World, with the first major split and subsequent diversification of *Cuscuta* species in the New World most likely occurring between South America and Mexico. They regarded Mexico as the centre of biodiversity for *Cuscuta* and a staging ground for subsequent diversification.

¹²⁰ Possibly *Cu. australis*, not *Cu. campestris*. See next footnote.

¹²¹ For recent information on synonyms within the genus *Cuscuta* see: O'Driscoll CW. 2003. Preliminary review of the genus *Cuscuta* in North America. Prepared for the NAPPO PRA Panel – July/August 2003. North American Plant Protection Organization. 10 pp. <http://www.nappo.org/PRA-sheets/CuscutaTable2003.pdf>. Although she lists *Cu. pentagona* as a synonym of *Cu. campestris* evidence presented by Stefanović et al. (2007) indicates that it is not.

In addition to transmission of HLB by *Cuscuta* spp., transmission by another parasitic plant, dodder laurel (*Cassytha filiformis* L.¹²² [Magnoliales: Lauraceae]) may prove possible. This possibility is based on reports of successful transmission of citrus mosaic (Reddy et al. 1985), CTV (Reddy & Murti (1988), citrus yellow corky vein (Reddy & Naidu 1989), and of a mycoplasma-like organism from coconut (*Cocos nucifera* [Arecales: Arecaceae]) to periwinkle Saskikala et al. (1989).

Version 2

¹²² *Ca. filiformis* is a leafless, climbing, twining, vine-like, autoparasitic and plant-hyperparasitic phanerogam. It is indigenous to Hawaii and infests a wide variety of plants, mainly woody hosts, including plants of agricultural and economic value, throughout the tropics worldwide. It belongs to a genus with about 20 species, and occurs in Australia. Hosts of economic importance include citrus, and it may cover and parasitise dozens of host species simultaneously (Nelson 2008).

Appendix IV. Spread of Huanglongbing through Asia

China. As noted in Appendix III, it has been assumed, based on recollections of farmers in Chaozhou county, near Shantou (Swatow) (Lin 1956), and observations on citrus diseases and disorders by Reinking (1919), that HLB originated in China and was present there in the late 1800s (Zhao 1981, da Graça 1991, Bové 2006). However, Reinking's observations of dieback, mottled leaf and yellowing do not describe HLB, as concluded by Lin (1956), Zhao (1981), da Graça (1991) and Bové (2006). It is clear though, that HLB was a serious problem in the Chaozhou/Shantou region of Guangdong in the mid 1930s (Lin 1956). It is therefore possible that the HLB was not present, or not a problem in China, until the early 1900s.

In this context, it is important to note records on incidence of *D. citri* in China. Crawford (1917) speaks of the psyllid as 'a widely distributed species throughout the Orient, from India through China to the Philippines'. Clausen (1933) gave the distribution of *D. citri* as China, Philippine Islands, Taiwan, Malaya, Dutch East Indies, Burma, India and Ceylon, but Hoffmann (1936) could find not references to any specific localities for the 'bug' in China, and consequently no reference to its life history or economic status in the country. The first definitive record of *D. citri* in China was in 1934 (Jiang et al. 1935¹²³). These authors figured a nymph of a psyllid that they considered to be *Diaphorina* (*Euphalerus*) *citri* Kuwayama and the species was briefly discussed (Jiang et al. 1935). At the time, psyllids were believed to be of little importance on citrus in Guangdong (Hoffmann 1936). The identity of the psyllid was confirmed shortly afterwards and observations in 1935 showed that *D. citri* was of 'considerable consequence', in some instances 'literally swarming with nymphs and adults' in the province (Hoffmann 1936). Hoffmann¹²⁴ compared the situation in Guangdong with records in the Punjab, where the psyllid was known to be serious pest capable of in India causing branch and tree death (Husain & Nath 1927), and Southeast Asia, where Clausen (1933) stated that *D. citri* did not assume a destructive status in the Philippine Islands, Malaya or the Dutch East Indies, and in Taiwan where Shiraki (1934ab) described it as being 'somewhat injurious'. Hoffmann (1936) also mentioned that in Honam Island (= Henan Dao, in modern Guangzhou) some trees were considerably damaged by *D. citri* attack and that searches failed to reveal the presence of any parasitoids. He rated hosts, in order of preference, as lemon (*C. × limon*, cited as *C. limonia* Osbeck), Huangpi or Wampee (*Cl. lansium*), Kam (*C. × aurantium*, cited as *C. nobilis*), Kat (*C. reticulata*, cited as *C. nobilis* var. *delicosa*), sweet orange (*C. × aurantium*, cited as *C. sinensis* Osbeck) and pomelo (*C. maxima*, cited as *C. grandis* Osbeck). He did not mention *M. paniculata* or *M. exotica*.

HLB is now prevalent in the Guangxi Autonomous Region and the provinces of Yunnan, Guangdong and Fujian, and southern regions of the provinces of Zhejiang, Jiangxi, Guizhou, Sichuan and Hunan (Zhao 2006). The historical background to citrus production in Guangxi and the appearance and spread of HLB has been given by Zhao (1987). Before 1950, seedling or marcotted trees were planted in backyards or in small orchards with nursery trees produced locally. But there were some grafted trees of Xinhui Cheng and Ponkan from Guangdong and Satsuma from Japan, planted in a limited area. After 1954 national citrus farms of 100-400 ha were planted, with some small orchards planted by farmers. A large citrus nursery was established and trees of the above varieties, as well as trees propagated from the uncontrolled introduction of budwood of Anliucheng and Tankan from Guangdong, were distributed throughout Guangxi. Zhao (1987) noted that HLB appeared, and intensified, in these new plantings in the late 1950s or early 1960s. Surveys in 1973-

¹²³ Jiang Zhi was a pseudonym of Ira Judson Condit (1883-1981), who was a visiting professor of horticulture at Lingnan University, Guangzhou (Canton) in 1934-35. He travelled extensively in Hawaii, China (including Taiwan), Philippines and Japan.

¹²⁴ William Hoffmann also published under the pseudonym of He Fuming (Mandarin, in Cantonese Ho Fuman). He commenced his studies on pests of citrus in Guangdong in 1926 (Jiang et al. 1935). He was based at Lingnan University from 1924 to 1951 (Wang D. 2007. Managing God's Higher Learning: U.S.-China Cultural Encounter and Canton Christian College (Lingnan University) 1888-1952. Lanham, Maryland: Lexington Books.)

1977 showed no natural spread of HLB in the extreme northern part of Guangxi in the absence of the psyllid, but epidemics of HLB in the south which correlated with high populations of *D. citri*. An apparent northward expansion of HLB occurred in Guangxi in the 1980s with the appearance of *D. citri* and in Zhejiang in early 2000 (Zhao 2006).

The current distribution of *D. citri* in China was recently reviewed by (Yang et al. 2006). Quoting several authors, they noted that the highest infestations of the psyllid, and therefore the highest incidence of HLB, occur in Guangxi, Guangdong, Fujian, and Taiwan in the southeast sector of the country, with the boundary separating high from low incidence running from 29°N in Zhejiang to 25°N in Yunnan in a sea-facing convex arc running slightly inland from the mountain ranges that separate inland Sichuan, Guizhou, Hunan and Jiangxi from coastal Guangxi, Guangdong, Fujian and Zhejiang. They also noted that the records extended further northwards, particularly along river valleys, to between 24°N and 28°N in inland Sichuan, Guizhou, Hunan and Jiangxi and 29°N in coastal Zhejiang. Relatively warm conditions, particularly consecutively warm winters, have led to northerly expansion of boundaries for the distribution of *D. citri* and HLB in Guangxi, Fujian, Zhejiang and Guizhou, and movement of populations to higher altitudes within all regions. In suitably warm winters, host plants produce flush growth suitable for the development and continuity of psyllid populations and an increase in the number of annual generations. Expansion of commercial citrus production and propagation of alternative hosts has also enhanced spread of populations to higher latitudes and altitudes, and winds from the South China Sea assisted northward expansion of *D. citri* populations in Guilin in Guangxi by 0.5° latitude in 1982 and 1987. Strong southerly winds also influence populations in the neighbouring regions of northern Guangxi and southern Hunan from June to August each year.

A large scale migration of people to Taiwan from the coastal areas of Fujian (Fukien) and Guangdong (Kwangtung) Provinces of southern mainland China occurred during the 17th Century. Planting material of citrus was carried by these migrants and this is the origin of most of the citrus types in Taiwan. As late as 1930 propagating material of Ponkan and Tankan were imported to Taiwan from mainland China (Spurling 1969).

Indonesia: Tirtawidjaja et al. (1965) were the first to note the presence of HLB (citrus vein-phloem degeneration 'virus') in Indonesia. They commented that it had been spreading in Indonesia from 1950. Its importance was felt as early as 31 July 1948 in the Pasar Minggu area on Siam mandarin (Cortez 1973 in Aubert et al. 1985). In 1964, the disease was widespread in Java and surveys before 1980 showed that it was also present in Sumatra, but not in Borneo, Sulawesi, Madura, Lombok and of limited occurrence in backyards in Makassar (Tirtawidjaja 1980). The widespread occurrence of HLB in Java and Sumatra was attributed by Tirtawidjaja (1980) to movement of a certain mandarin variety from nurseries in Pasarminggu in Jakarta. Aubert (2000) commented that it was through Javanese planting material that HLB and *D. citri* were disseminated over the entire archipelago. However, he noted that its presence in Ende and Timor, where it had only recently been introduced, was limited to scattered small foci and easy to eradicate. Weinert et al. (2004) detected HLB in Timor-Leste (East Timor) and in nearby Papua New Guinea, in Australasia (Davis et al. 2000).

Philippines: *D. citri* was recorded in the Philippines before 1917 (Crawford 1917, Clausen 1933, Hoffmann 1936) and was recognised as a citrus pest before 1921 (Catling 1968). Despite these records, HLB did not attract attention in the Philippines in certain plantings of Ladu (*C. reticulata* syn. *C. paratangerina* Hort. ex Tan.) and Szinkom (*C. reticulata* syn. *C. suhuiensis* Hort. ex Tan.) mandarins in Batangas Province until 1957 (Salibe & Cortez 1966, Martinez & Wallace 1967, 1968, Altamirano et al. 1976). By 1960, 60-90% of trees in some orchards were affected, and 1 million trees were declining in Batangas Province. Batangas was the source of propagating material for important citrus growing areas of the Philippines, including central and northern Luzon, Bicol,

Visayas and Mindanao (Martinez & Wallace 1969). The many similarities among the citrus vein-phloem degeneration (chlorosis), yellow shoot, likubin and leaf mottling, led Salibe & Cortez (1966) to suggest 'that these diseases may be caused by the same virus or strains of a virus that is spreading in the citrus-growing areas of Southeast Asia'.

Salibe & Cortez (1966), Martinez & Wallace (1969) and Altamirano et al. 1976) linked the origins of the disease to many introductions of budwood and small-budded trees from the Chinese mainland and Taiwan, India and Japan before 1957. da Graça (1991), da Graça & Korsten (2004), Bové (2006) and Gottwald et al. (2007) cite Lee (1921) as the first record HLB in the Philippines (at Lamao in Bataan Province). However, the symptoms Lee (1921) described resembled zinc deficiency and were not identical to the symptoms now known to be caused by HLB. Moreover, Lee (1921) specifically said 'the type of mottling was entirely the same as that seen in California' and attributable to malnutrition, and he did not mention the presence of psyllids or aphids at Lamao. Furthermore, Wallace (1978), in reviewing leaf-mottle yellows disease in the Philippines, concluded that the 'mottle leaf' studied by Lee (1921), was caused by zinc deficiency and the severity of leaf mottle on trees on pomelo was due to the susceptibility of the stock to citrus tristeza virus.

There was great increase in citrus acreage, particularly mandarins in Batangas region of Luzon from 1948 following World War II, to 1961, when it reached its peak (Martinez & Wallace 1969, Spurling 1969, Wallace 1978). The Ladu mandarin (from Saharangpur (Saharanpur), Uttar Pradesh, India) and Szinkom mandarin (originally from China) were both introduced to the Philippines from India in 1912 and 1914 (Benemerito 1956, Hodgson 1967, Spurling 1969). Four other mandarin types ('Szwui Kom', 'Ponkan', 'Sunwui kom' and 'T'ai Kat', all from Guangdong), two pomelo selections ('Mantan Yau' from Xiamen, Fujian, and 'Sunwui Yau' from Guangdong), and a sweet orange variety ('Sunwui T'im Ch'ang) were introduced to the Philippines by Benemerito on one or more occasions between 1931 and 1939 (Benemerito 1956). Another pomelo selection, 'Kao Phuang', was introduced from Thailand in 1920 (Groff 1927, Spurling 1969) and a Ponkan selection was also introduced in 1927 from Guangdong (Benemerito 1956)¹²⁵.

It seems unlikely, given the above, and our conclusions concerning HLB in China, that HLB was present in the Philippines until the mid to late 1940s. This suggests that the disease was introduced to the Philippines after World War II, possibly from China.

Thailand. Citriculture in Thailand was described in 1680 by the French missionary Delaloubles, but is much older (Aubert 2000). It was a thriving industry in 1955 (Wahlberg 1956), but in the 1960s, orchards began to decline rapidly (Schwarz et al. 1973a). By 1973, the disease was severe in some regions but absent in others (Schwarz et al. 1973b). This discontinuous distribution was noted by Schwarz et al. (1973a), to also occur throughout eastern Asia, including the Philippines and Indonesia, and they commented that there was increasing evidence that the disease was not indigenous to Southeast Asia. Roistacher (1994) wrote: 'In my life-time of involvement with citrus virus and virus like diseases, never have I witnessed such severe destruction of citrus as seen in this consultancy visit through Thailand. This destruction of citrus by the citrus greening disease has been ongoing in Thailand for over 30 years and has been well documented by others. I believe there is a tendency to accept and accommodate the disease and to live with it. I observed that after a period of destruction by greening disease, the trees become unproductive and unprofitable after 5 to 8 years'. The disease is assumed to have been introduced accidentally to Thailand in the early 1960s (Aubert 2000), but there is no apparent record of when *D. citri* first occurred in the country.

¹²⁵ Ponkan or Batanges, though also known as the Swatow orange, originated in India where it is called Suntara or Nagpur Suntara (Hodgson 1967, Spurling 1969). It is synonymous with the Australian Emperor mandarin: Coletta Filho HD, Machado MA, Luiza M, Targon PN, Pompeu J. 2000. The use of random amplified polymorphic DNA to evaluate the genetic variability of Ponkan mandarin (*Citrus reticulata* Blanco) accessions. Genetics and Molecular Biology 23: 169-172.

Reinking & Groff (1921) did not mention *D. citri* as pest of pomelo in Thailand, and the only reference to mottled leaves was 'A typical mottle leaf with yellow areas between green veins. Little damage is done by them.' 'Yellowing was commonest when irrigation was not properly practiced.'

Malaysia

Symptoms of HLB were first noticed in Malaysia in the 1970s (Ko 1988, 1991) and its presence was confirmed in 1989 (Lim et al. 1990a). Information provided by Ko (1991) and Saamin et al. (1991) suggest that the first record of the disease in Peninsular Malaysia may have been related to the introduction of *C. reticulata* seedlings (in this instance Tanaka's *C. suhuiensis*, a mandarin variety from Sihui near Guangzhou in Guangdong) to Terengganu from China in the 1950s and 1960s. However, Lim et al. (1990a) speculated that the disease may have been present 'in the country since early 1900'. Although this seems unlikely, given other records including Ko (1991) and Saamin et al. (1991), Lim et al. (1990a) suggested that 'the disease was probably introduced unknowingly when the immigrants then brought along with them mottled orange materials which harboured the greening pathogen. The popular limau langkat or *C. suhuiensis* is believed to have originated from the Suhui district of Kwangtung (Guangdong) Province in China (Tanaka 1954, Ko 1988¹²⁶). Other local varieties of Chinese origin are Kwangtung mandarin, Liukan, Tankan and Ponkan (Ko 1988). Clones of other Asian countries eg Thailand and Indonesia have also found their way into the country usually through illegal means'.

The earliest commercial citrus crops (limes and later mandarin oranges) were established between about 1915 and 1925 (Jones & Ibrahim 1984). Vast mandarin orange (*C. suhuiensis*) plantings totalling 2,500 ha in the states of Kelantan, Terengganu, Perak and Johore during the 1950s were devastated in the 1960s (Jones & Ibrahim 1984, Ko 1991). This was attributed to *Phytophthora* root rot by Jones & Ibrahim (1984), but Ko (1991) noted that there regions where *Phytophthora* infection was not the cause of decline and that affected species and varieties were CTV tolerant. Jones & Ibrahim (1984) mentioned that almost all plantings were local varieties native to Malaysia or uncontrolled introductions from Thailand (*C. suhuiensis*), Philippines (*C. suhuiensis*), China (king mandarin, '*C. nobilis*'), Taiwan and elsewhere.

¹²⁶ Cited in the references of this IMP as Ko (1988).

Appendix V: Hosts of huanglongbing

Table 1. Known Aurantioideae: Aurantieae species and hybrids recorded as hosts of HLB: in the last column pathogen 'species' to which observations pertain are denoted as **Laf** for '*Candidatus Liberibacter africanus*', **Lam** for '*Ca. L. americanus*', and **Las** for '*Ca. L. asiaticus*'¹²⁷.

Species or hybrid	Cited as	Common names	Original citations	Pathogen, diagnostic method and comments
<i>Aeglopsis chevalieri</i> Swingle	<i>Aeglopsis chevalieri</i> Swingle		Martinez & Wallace 1969; Koizumi et al. 1996	Las : symptomless host (Martinez & Wallace); questionable symptoms after vector transmission (<i>D. citri</i>) (Koizumi et al.).
<i>Atalantia buxifolia</i> (Poir.) Oliv.	<i>Severinia buxifolia</i> (Poiret) Ten.	Chinese box orange	Martinez & Wallace (1969); Su et al. 1995; Koizumi et al. 1996; Hung et al. 2000, 2001; Deng et al. 2008b	Las : slight yellowing and faint mottling and slight stunting (Martinez & Wallace); DNA hybridisation (Su et al.); graft transmission from sweet orange infected with Las and citrus tristeza virus detected by dot hybridisation, and chlorosis noted (Hung et al. 2000, 2001); <i>D. citri</i> transmission to and from plants, and natural host in field (Hung et al. 2001); stunting after vector transmission (Koizumi); The leaf mottle/yellowing but no significant effect on plant growth; and graft transmission to mandarin (Deng et al.)
<i>Balsamocitrus dawei</i> Stapf	<i>Balsamocitrus dawei</i> Stapf		Koizumi et al. 1996	Las : suspicious symptoms after vector transmission
<i>Citrus amblycarpa</i> (Hassk.) Ochse	<i>Citrus amblycarpa</i> Ochse		Tirtawidjaja 1981	Las : transmission by <i>D. citri</i> from infected citrus (based on internal phloem degeneration, external mottling and chlorosis, and stunting)
<i>Citrus australasica</i> F. Muell.	<i>Microcitrus australasica</i> (F. J. Muell.) Swingle		Koizumi et al. 1996	Las : stunting after vector transmission
<i>Citrus cavaleriei</i> H. Léveillé ex Cavalerie	<i>Citrus ichangensis</i> Swingle	Ichang (Yichang) papeda	Fraser & Singh 1969; Miyakawa & Zhao 1990	Las : fairly tolerant (Fraser & Singh); symptoms (Miyakawa & Zhao)
<i>Citrus hystrix</i> DC.	<i>Citrus macroptera</i> Montrouz. <i>Citrus hystrix</i> DC		Fraser & Singh 1969	Las : no leaf symptoms
			Fraser & Singh 1969; Miyakawa & Zhao 1990	Las : fairly tolerant (Fraser & Singh); symptoms (Miyakawa & Zhao)
<i>Citrus japonica</i> Thunb.	<i>Fortunella</i> sp. <i>Fortunella hindsii</i> <i>Fortunella japonica</i>		Miyakawa & Zhao 1990 Li et al. 2007a Li et al. 2007a	Las : symptoms Las: cryptic symptoms Las: cryptic symptoms
<i>Citrus maxima</i> (Burm.) Merr.	<i>Citrus grandis</i> (L.) Osbeck		Nariani et al. 1973; Schwarz et al. 1973a; Nariani 1981; van Lelyveld & van Vuuren 1988; Manicom & van Vuuren 1990; Miyakawa & Zhao	Las : tolerant (Nariani et al.); susceptible (Nariani); 'som-o' rather tolerant (Schwarz et al.); symptoms (Miyakawa & Zhao); pomelo-infecting strain

¹²⁷ Good photographs of some Australasian species, excluding those from New Caledonia, can be viewed on Mike Saalfeld's website (<http://www.saalfelds.freeseerve.co.uk/HobbyCitrusGrowers.htm>).

			1990; Su & Huang 1990	prevalent since 1970s (Su & Huang); Laf : susceptible (van Lelyveld & van Vuuren); tolerant (Manicom & van Vuuren)
	<i>Citrus maxima</i> (Burm.) Merr.	pomelo, pummelo	Fraser & Singh 1969	Las : tolerant
	<i>Citrus</i> sp.	pomelo/shaddock	Miyakawa & Zhao 1990	Las : symptoms
		pomelo	Gonzales et al. 1972; Aubert et al. 1985	Las : susceptibility in decreasing order: sweet orange, pomelo and grapefruit, mandarin and mandarin/sweet orange hybrids, trifoliate orange and its hybrids, and selections of lemons, sweet limes and sour orange (Gonzales et al.); more tolerant than oranges and mandarins (Aubert et al.)
<i>Citrus medica</i> L.	<i>Citrus medica</i> L.	citron	Fraser & Singh 1969; Su & Matsumoto 1972; Nariani 1981	Las : fairly tolerant (Fraser & Singh); yellow mottling after grafting (Su & Matsumoto); 'highly susceptible' (Nariani 1981)
<i>Citrus reticulata</i> Blanco	<i>Citrus depressa</i> Hayata	flat lemon	Miyakawa & Zhao 1990	symptoms
	<i>Citrus keraji</i> Hort. ex Tanaka	kabuchi	Miyakawa & Zhao 1990	Las : symptoms
	<i>Citrus oto</i> Hort. ex Yu. Tanaka	Oto-mikan	Miyakawa & Zhao 1990	Las : symptoms
	<i>Citrus reticulata</i> Blanco		Tirtawidjaja 1965 et al.; Tirtawidjaja 1981; Manicom & van Vuuren 1990; Miyakawa & Zhao 1990	Las : phloem degeneration after feeding by field collected <i>D. citri</i> - first record of possible transmission (Tirtawidjaja et al.); transmission by <i>D. citri</i> from infected citrus (based on internal phloem degeneration, external mottling and chlorosis, and stunting) (Tirtawidjaja); symptoms (Miyakawa & Zhao); Laf : severe symptoms (Manicom & van Vuuren)
	<i>Citrus reticulata</i> Blanco	native Indian mandarins from Assam, Kalimpong, and other hill areas	Fraser & Singh 1969	Las : highly intolerant
	<i>Citrus reticulata</i> Blanco	Kinnow and other mandarin hybrids	Fraser & Singh 1969	Las : highly intolerant
	<i>Citrus reticulata</i> Blanco	many Indian mandarins including Nagpur and Coorg and imported selections of Clementine, Ladu and Emperor	Fraser & Singh 1969	Las : very severe when infected as nursery trees but less severe (intolerant) when infected as older or mature trees; possible regional strain variation
	<i>Citrus reticulata</i> Blanco	ponkan	Su & Matsumoto 1972	Las : chlorosis, vein yellowing & corking, dieback after grafting
	<i>Citrus reticulata</i> Blanco	Cleopatra and some native mandarins	Fraser & Singh 1969	Las : tolerant with occasional foliar symptoms but little twig dieback
	<i>Citrus suhuiensis</i> Hort. ex Tanaka	Szinkom	Su & Matsumoto 1972	Las : leaf chlorosis & atrophy, stunting after grafting (Su & Matsumoto)

	<i>Citrus sunki</i> Hort. ex Tanaka		Su & Matsumoto 1972; Miyakawa & Zhao 1990	Las: chlorosis, vein corking (Su & Matsumoto), symptoms (Miyakawa & Zhao)
	<i>Citrus unshiu</i> (Mack.) Marc		Miyakawa & Zhao 1990	Las: symptoms
	<i>Citrus unshiu</i> (Mack.) Marc	Satsuma	Fraser & Singh 1969	Las: fairly tolerant
	<i>Citrus</i> sp. (mandarins)		Miyakawa & Zhao 1990	Las: symptoms
		mandarins & mandarin/sweet orange hybrids	McClellan & Schwarz 1970	Laf: susceptibility in decreasing order: sweet orange with some variation, mandarins with some, e.g., Satsuma, more susceptible than sweet orange, grapefruit, tangeloes, with some, e.g. Orlando and Minneola, very susceptible , trifoliate orange, Troyer citrange, lemons, West Indian lime, sour orange
		mandarins & mandarin/sweet orange hybrids	Gonzales et al. 1972	Las: susceptibility in decreasing order: sweet orange, pomelo and grapefruit, mandarin and mandarin/sweet orange hybrids , trifoliate orange and its hybrids, and selections of lemons, sweet limes and sour orange
		various cultivars	Koizumi et al. 1993, 1994	Las: of some 33 cultivars observed in the field, more than 50% were mildly 'resistant', or more so, particularly satsum', som-keaw, ladu and som-pan cultivars
<i>Citrus</i> sp.	<i>Citrus limettioides</i> Tanaka	sweet lime	Fraser & Singh 1969	Las: quite tolerant
	<i>Citrus latipes</i> (Swingle) Tanaka		Fraser & Singh 1969	Las: tolerant
<i>Citrus trifoliata</i> L.	<i>Poncirus trifoliata</i> (L.) Raf.	trifoliata	Martinez & Wallace 1969; Miyakawa 1980; Nariani 1981; Manicom & van Vuuren 1990; Miyakawa & Zhao 1990; Koizumi et al. 1996	Las: symptomless host (Martinez & Wallace); back inoculations (Miyakawa, Miyakawa & Zhao); symptoms fairly intense (Nariani); suspicious symptoms after vector transmission and plants died by possibly not due to the pathogen (Koizumi et al.); Laf: tolerant (Manicom & van Vuuren)
	<i>Poncirus trifoliata</i> (L.) Raf.	trifoliate orange and hybrids	Fraser & Singh 1969; Martinez & Wallace 1969	Las: fairly tolerant with prominent leaf symptoms but less severe tree deterioration (Fraser & Singh); symptomless host (Martinez & Wallace)
		trifoliate orange	McClellan & Schwarz 1970	Laf: susceptibility in decreasing order: sweet orange with some variation, mandarins with some, e.g., Satsuma, more susceptible than sweet orange, grapefruit, tangeloes, with some, e.g., Orlando and Minneola, very susceptible, trifoliate

		trifoliolate orange and its hybrids	Gonzales et al. 1972	orange , Troyer citrange, lemons, West Indian lime, sour orange Las : susceptibility in decreasing order: sweet orange, pomelo and grapefruit, mandarin and mandarin/sweet orange hybrids, trifoliolate orange and its hybrids , and selections of lemons, sweet limes and sour orange (Gonzales et al.)
<i>Citrus × aurantiifolia</i> (Christm.) Swingle	<i>Citrus aurantifolia</i> (Christm.) Swingle	limes	Schwarz et al. 1973a; Tirtawidjaja 1981; Manicom & van Vuuren 1990; Miyakawa & Zhao 1990	Las : HLB symptoms in 'manao' masked by tristeza (Schwarz et al.); transmission by <i>D. citri</i> from infected citrus (based on internal phloem degeneration, external mottling and chlorosis, and stunting) (Tirtawidjaja); mild symptoms (Miyakawa & Zhao); Laf : tolerant (Manicom & van Vuuren)
		limes	McClean & Schwarz 1970	Laf : susceptibility in decreasing order: sweet orange with some variation, mandarins with some, e.g., Satsuma, more susceptible than sweet orange, grapefruit, tangeloes, with some, e.g., Orlando and Minneola, very susceptible, trifoliolate orange, Troyer citrange, lemons, West Indian lime, sour orange
		limes	Gonzales et al. 1972	Las : susceptibility in decreasing order: sweet orange, pomelo and grapefruit, mandarin and mandarin/sweet orange hybrids, trifoliolate orange and its hybrids, and selections of lemons, sweet limes and sour orange
	<i>Citrus aurantifolia</i> (Christm.) Swingle	West Indian lime	van Lelyveld & van Vuuren 1988	Laf : slightly susceptible
	<i>Citrus limmetioides</i> Tan (sic)	sweet lime	Nariani et al. 1973	Las : tolerant
<i>Citrus × aurantium</i> L.	<i>Citrus aurantium</i> L.	sour orange	Miyakawa & Zhao 1990	Las : symptoms
	<i>Citrus aurantium</i> L.	sour orange	Fraser & Singh 1969; van Lelyveld & van Vuuren 1988; Manicom & van Vuuren 1990	Las : similar to grapefruit; Laf : susceptible (van Lelyveld & van Vuuren); moderate symptoms (Manicom & van Vuuren)
		grapefruit, sweet orange & sour orange	McClean & Schwarz 1970	Laf : susceptibility in decreasing order: sweet orange with some variation, mandarins with some, e.g., Satsuma, more susceptible than sweet orange, grapefruit , tangeloes, with some, e.g., Orlando and Minneola, very susceptible, trifoliolate orange, Troyer citrange,

	grapefruit, sweet orange & sour orange	Gonzales et al. 1972	lemons, West Indian lime, sour orange (McClellan & Schwarz) Las: susceptibility in decreasing order: sweet orange , pomelo and grapefruit , mandarin and mandarin/sweet orange hybrids, trifoliolate orange and its hybrids, and selections of lemons, sweet limes and sour orange .
<i>Citrus hassaku</i> Hort. ex Tanaka	hassaku orange	Miyakawa & Zhao 1990	Las: symptoms
<i>Citrus karna</i> Raf.		Fraser & Singh 1969	Las: very tolerant
<i>Citrus maderaspatana</i> hort. ex Tanaka		Fraser & Singh 1969	Las: tolerant
	various cultivars	Nariani 1981; Koizumi et al. 1993, 1994	Las: 7 selections 'highly susceptible' (Nariani) of some 19 cultivars observed in the field, more 17 were susceptible and 2 were mildly 'resistant' (Koizumi et al. 1993, 1994)
<i>Citrus natsudaoidai</i> Hayata	natsudaoidai (neck orange)	Koizumi et al. 1993, 1994	Las: few or mild symptoms in field observations but trees lost vigour and attached leaves were small and scattered
<i>Citrus nobilis</i> Lour.	Ortanique	Koizumi et al. 1996	Las: symptoms
<i>Citrus nobilis</i> Lour.		Koizumi et al. 1996	Las: symptoms
<i>Citrus sinensis</i> (L.) Osbeck	sweet orange	Su & Matsumoto 1972; van Lelyveld & van Vuuren 1988; Manicom & van Vuuren 1990; Miyakawa & Zhao 1990	Las: leaf chlorosis, mottling & atrophy, stunting after grafting (Su & Matsumoto); symptoms, presence of putative pathogen in tissue (Miyakawa & Zhao) Laf: highly susceptible (van Lelyveld & van Vuuren); severe symptoms especially blood oranges (Manicom & van Vuuren)
	tankan	Su & Matsumoto 1972	Las: chlorosis, vein yellowing & corking, dieback after grafting
<i>Citrus sinensis</i> (L.) Osbeck	Blood Red, Mosambi, Jaffa, Valencia, Hamlin and Sathgudi sweet oranges	Fraser & Singh 1969	Las: highly intolerant, severely affected, Blood Red and Mosambi deteriorated most rapidly (Fraser & Singh)
	grapefruit	Fraser & Singh 1969; van Lelyveld & van Vuuren 1988; Manicom & van Vuuren 1990	Las: severe in young trees with progress of tree deterioration severe but longer than in sweet orange (Fraser & Singh); Laf: susceptible (van Lelyveld & van Vuuren); moderate symptoms (Manicom & van Vuuren)
<i>Citrus paradisi</i> Macfad.	grapefruit	Miyakawa & Zhao 1990	Las: symptoms
	Minneola tangelo	van Lelyveld & van Vuuren 1988; Manicom & van Vuuren 1990	Laf: highly susceptible/severe symptoms
	Orlando tangelo	Manicom & van Vuuren 1990	Laf: severe symptoms

<i>Citrus × insitorum</i> Mabb.		Yalaha & Orlando tangeloes	Fraser & Singh 1969	Las: highly intolerant
		Troyer and Carrizo citrange	Martinez & Wallace 1969; Nariani 1981	Las: symptomless hosts (Martinez & Wallace); symptoms fairly intense (Nariani)
		Troyer citrange	McClean & Schwarz 1970; Manicom & van Vuuren 1990	Laf: susceptibility in decreasing order: sweet orange with some variation, mandarins with some, e.g., Satsuma, more susceptible than sweet orange, grapefruit, tangeloes, with some, e.g., Orlando and Minneola, very susceptible, trifoliate orange, Troyer citrange , lemons, West Indian lime, sour orange (McClean & Schwarz); tolerant (Manicom & van Vuuren)
	× <i>Citroncirus webberi</i> J. Ingram & H. E. Moore	Carrizo citrange	Miyakawa & Zhao 1990;	Las: symptoms (few) stunting, seed abortion (Miyakawa & Zhao)
<i>Citrus × junos</i> Siebold ex Tanaka	<i>Citrus junos</i> Sieb. ex Tanaka	Yuzu	Miyakawa & Zhao 1990	Las: symptoms
<i>Citrus × limon</i> (L.) Osbeck	<i>Citrus assamensis</i> S. Dutta & S.C. Bhattach.		Fraser & Singh 1969	Las: tolerant
	<i>Citrus limetta</i> (Risso)	sweet lime	Nariani 1983	Las: 'resistant'
	<i>Citrus limon</i> (L.) Burm. f.		Miyakawa & Zhao 1990	Las: symptoms, presence of putative pathogen in tissue (Miyakawa & Zhao); plant reported tolerant to disease, but source of vectors (Lee 1996)
	<i>Citrus limon</i> (L.) Burm. f.	acid limes	Fraser & Singh 1969	Las: tolerant
	<i>Citrus limon</i> (L.) Burm. f.	lemon	Fraser & Singh 1969; Manicom & van Vuuren 1990	Las: fairly tolerant with prominent leaf symptoms but less severe tree deterioration (Fraser & Singh) Laf: moderate symptoms (Manicom & van Vuuren)
	<i>Citrus limonia</i> Osbeck		Tirtawidjaja 1981; Miyakawa & Zhao 1990	Las: transmission by <i>D. citri</i> from infected citrus (based on internal phloem degeneration, external mottling and chlorosis, and stunting) (Tirtawidjaja); symptoms (Miyakawa & Zhao)
	<i>Citrus limonia</i> Osbeck	Rangpur ¹²⁸	Fraser & Singh 1969; Su & Matsumoto 1972	Las: tolerant (Fraser & Singh); yellow mottling after grafting (Su & Matsumoto)
	<i>Citrus meyeri</i> Tan.	Meyer lemon	Fraser & Singh 1969 McClean & Schwarz 1970; van Lelyveld & van Vuuren 1988	Las: fairly tolerant Laf: susceptibility in decreasing order: sweet orange with some variation, mandarins with some, e.g., Satsuma, more susceptible than sweet orange, grapefruit, tangeloes, with some, e.g. Orlando and Minneola,

¹²⁸ Rangpur lime is of uncertain parentage and the name appears to have been used for more than one cultivar. Fraser & Singh (1969) also referred to the plant as marmalade orange.

		lemons	Gonzales et al. 1972	very susceptible, trifoliolate orange, Troyer citrange, lemons , West Indian lime, sour orange (McClellan & Schwarz); susceptible (van Lelyveld & van Vuuren)
<i>Citrus × latifolia</i> (Yu. Tanaka) Tanaka	<i>Citrus latifolia</i> (Yu. Tanaka) Tanaka	Tahiti lime	Fraser & Singh 1969; van Lelyveld & van Vuuren 1988	Las : susceptibility in decreasing order: sweet orange, pomelo and grapefruit, mandarin and mandarin/sweet orange hybrids, trifoliolate orange and its hybrids, and selections of lemons , sweet limes and sour orange
<i>Citrus × microcarpa</i> Bunge		calamandarin	Su & Matsumoto 1972; Koizumi et al. 1993, 1994	Las : leaf chlorosis & atrophy, stunting after grafting (Su & Matsumoto); regarded as tolerant in field observations with mild symptoms, some dieback and slow disease progression (Koizumi et al.)
<i>Citrus × taitensis</i> Risso	<i>Citrus jambhiri</i> Lushington		Tirtawidjaja 1981; Koizumi et al. 1993, 1994	Las : transmission by <i>D. citri</i> from infected citrus (based on internal phloem degeneration, external mottling and chlorosis, and stunting) (Tirtawidjaja); selections regarded as tolerant in field observations with mild symptoms, some dieback and slow disease progression (Koizumi et al.)
	<i>Citrus jambhiri</i> Lushington	rough lemon	Fraser & Singh 1969; van van Lelyveld & van Vuuren 1988; Manicom & van Vuuren 1990	Las : relatively tolerant; Laf : susceptible (van Lelyveld & van Vuuren); moderate symptoms (moderate symptoms (Manicom & van Vuuren)
<i>Limonia acidissima</i> L.	<i>Limonia acidissima</i> L.		Koizumi et al. 1996; Su et al. 1995; Hung et al. 2000	Las : symptoms after vector transmission, and in suckers when used as a rootstock of infected <i>C. reticulata</i> scion (Koizumi); DNA hybridisation (Su et al.); graft transmission from sweet orange infected with Las and citrus tristeza virus detected by dot hybridisation, and chlorosis noted: infection apparently temporary (Hung et al.)
<i>Murraya paniculata</i> (L.) Jack (<i>sensu lato</i>)	<i>Murraya paniculata</i> (L.) Jack		Tirtawidjaja 1981; Aubert et al. 1985; Miyakawa 1980; Koizumi et al. 1996; Toorawa 1998; Dai et al. 2005; Lopes 2006; Lopes et al. 2005, 2006a,b; Li et al. 2007a; Zhou et al. 2007; Deng et al. 2007;	Las : suspicious symptoms: external and internal symptoms like CVPD after vector transmission (Tirtawidjaja); transmission by <i>D. citri</i> from infected citrus (based on internal phloem

			Manjunath et al. 2008	degeneration, external mottling and chlorosis, and stunting) (Tirtawidjaja); can harbour greening organism (Aubert et al.). EM negative (Miyakawa); no symptoms (Koizumi et al.); not a host (Toorawa); not a host: no graft transmission from infected citrus (Dai et al.); transmitted to citrus from <i>M. paniculata</i> plants via dodder (Zhou et al.); two psyllid nymph samples positive (Manjunath et al.); cryptic symptoms in field and after transmission by <i>D. citri</i> (Li et al.) presence of both Las (10%) and Lam (0.6%), and graft transmissions from <i>Murraya</i> to <i>Murraya</i> and citrus to <i>Murraya</i> , but not from <i>Murraya</i> to citrus because of graft incompatibility (Lopes)
	<i>Murraya paniculata</i> var <i>paniculata</i>	common jasmine orange	Hung et al. 2000	Las : no symptoms and no detection by dot hybridisation after attempted graft transmission from sweet orange infected with Las and citrus tristeza virus
	<i>Murraya paniculata</i> var <i>Jiulixiang</i>		Li & Ke 2002	host
<i>Pamburus missionis</i> (Wight) Swingle	<i>Atalantia missionis</i> Oliver		Tirtawidjaja 1981	Las : transmission by <i>D. citri</i> from infected citrus (based on internal phloem degeneration, external mottling and chlorosis (Tirtawidjaja);
<i>Swinglea glutinosa</i> (Blanco) Merr.	<i>Swinglea glutinosa</i> (Blanco) Merr.		Tirtawidjaja 1981	Las : transmission by <i>D. citri</i> from infected citrus (based on internal phloem degeneration, external mottling and chlorosis (Tirtawidjaja);
<i>Triphasia trifolia</i> (Burm. f.) P. Wilson	<i>Triphasia trifolia</i> (Burm. f.) P. Wilson		Koizumi et al. 1996	Las : suspicious symptoms and severe stunting after vector transmission
Unknown (possibly a species or species of <i>Atalantia</i> , <i>Citrus</i> , <i>Pamburus</i>)	<i>Atalantia</i> sp.	unknown	Koizumi et al. 1996	no symptoms after vector transmission (Koizumi)
Unknown (possibly <i>Triphasia trifolia</i> (Burm. f.) P. Wilson)	<i>Atalantia trifolia</i>	unknown	Martinez & Wallace (1969)	symptomless host (Martinez & Wallace) but host name invalid and record possibly for <i>Triphasia trifolia</i> and not <i>Atalantia</i> or <i>Pamburus</i>

Table 2. Known Aurantioideae: Clauseneae species recorded as hosts of HLB: in the last column pathogen ‘species’ to which observations pertain are denoted as **Laf** for ‘*Candidatus Liberibacter africanus*’, **Lam** for ‘*Ca. L. americanus*’, and **Las** for ‘*Ca. L. asiaticus*’.

Species or hybrid	Cited as	Common name	Original citations	Pathogen, diagnostic method and comments

<i>Bergera koenigii</i> L.	<i>Murraya euchrestifolia</i> Hayata	curry leaf	Hung et al. 2000	Las: no symptoms and no detection by dot hybridisation after attempted graft transmission from sweet orange infected with Las and citrus tristeza virus
<i>Clausena anisata</i> (Willd.) Benth.	<i>Clausena inaequalis</i> (DC.) Benth.,	false horsewood	van den Berg et al. 1991-1992; van den Berg et al. (1992b)	Laa: graft transmission in field to sweet orange seedlings determined by symptoms and thin layer chromatography
<i>Clausena indica</i> Oliv.	<i>Clausena indica</i> (Dalz.) Oliver		Tirtawidjaja 1981; Miyakawa & Zhao 1990	Las: transmission by <i>D. citri</i> from infected citrus - based on stunting (Tirtawidjaja)
<i>Clausena lansium</i> (Lour.) Skeels	<i>Clausena lansium</i> (Lour.) Skeels	wampee, huangpi	Tirtawidjaja 1981; Koizumi et al. 1996; Ding et al. 2005	Las: stunting (Tirtawidjaja) suspicious symptoms after vector transmission (Koizumi); PCR detection of natural infection (Ding et al.)

Table 3. Known species of Rutoideae recorded as hosts of HLB: in the last column pathogen 'species' to which observations pertain are denoted as Laf for '*Candidatus Liberibacter africanus*' and **Laf-c** for '*Ca. L. africanus* subsp. capense'.

Species or hybrid	Cited as	Common name	Original citations	Pathogen, diagnostic method and comments
<i>Calodendrum capense</i> (L. f.) Thunb.	<i>Calodendrum capense</i>	Cape chestnut	Garnier et al. 2000	Laf-c: genomic characterisation
<i>Vepris lanceolata</i> (Lam.) G. Don	<i>Toddalia lanceolata</i>	white ironwood	Korsten et al. 1996	Laf: DNA/DNA hybridisation, PCR

Table 4. Known non-Rutaceae species recorded as hosts of '*Candidatus Liberibacter*': in the last column pathogen species to which observations pertain are denoted as **Laf** for '*Candidatus Liberibacter africanus*', **Lam** for '*Ca. L. americanus*', and **Las** for *Ca. L. asiaticus*.

Species or hybrid	Cited as	Common name	Original citations	Pathogen, diagnostic method and comments
<i>Catharanthus roseus</i> (L.) G. Don (Gentianales: Apocynaceae)	<i>Vinca rosea</i>	periwinkle	Tirtawidjaja 1981; Garnier & Bové 1983; Garnier et al., 1984a, b; Bové 2006a; Zhou et al., 2008	Las: transmission to citrus, to healthy periwinkle and to dodder (based on symptoms, mostly mottling); citrus to periwinkle and periwinkle to periwinkle by dodder; host shown by EM greater multiplication than in citrus (Garnier et al.); good host and possible seed transmission (Zhou et al); naturally infected plants never observed; psyllids dislike periwinkle, are unable to transmit the HLB agent to this plant, and die when forced to stay on it (Bové)
<i>Cuscuta</i> sp. (Convolvulaceae)	<i>Cuscuta</i> sp.: possibly <i>Cuscuta australis</i> R. Br.	dodder	Tirtawidjaja 1981	Las: transmission to rough lemon and periwinkle based (based on symptoms, mostly mottling)
<i>Cuscuta australis</i> R. Br. (Convolvulaceae)	<i>Cuscuta australis</i> R. Br., <i>Cuscuta campestris</i> &	dodder	Ghosh et al. 1977; Garnier & Bové 1983; Su & Huang	Las: observed to multiply in stems, haustoria and

	<i>Cuscuta pentagona</i>	1990; Duan et al. 2008b; Zhou et al 2008	flower stalks of <i>Cu australis</i> (Su & Huang) reaches high titres in <i>Cu. campestris</i> (Ghosh); citrus to periwinkle through <i>Cu. campestris</i> (Garnier and Bové) transmission by <i>Cu. pentagona</i> from sweet orange to tomato (Duan et al.); bacteria multiply well in <i>Cu. pentagona</i> with no symptoms (Zhou et al)
<i>Nicotiana tabacum</i> L. (Solanales: Solanaceae)	<i>Nicotiana xanthi</i> <i>Nicotiana tabacum</i> cv. Xanthi	Garnier & Bové 1993 Francischini et al. 2007	Las: symptoms, dodder transmission only Lam: Positive PCR detection in unique blotchy mottle symptomatic leaves after dodder transmission from sweet orange
<i>Solanum lycopersicum</i> L. (Solanales: Solanaceae)	<i>Lycopersicon esculentum</i> cvs. Manapal and FL47	Duan et al. 2008b	Las: dodder transmission from sweet orange shown by symptoms and PCR; lower titre than periwinkle

Appendix VI: Hosts of *D. citri*

Table 1. Known Aurantioideae: Aurantieae species on which the Asiatic citrus psyllid, *Diaphorina citri*, has been observed to rest, feed or complete its development¹²⁹.

Species or hybrid	Cited as	Common name	Original citations	Summary of observations
<i>Aegle marmelos</i> (L.) Corr.	<i>Aegle marmelos</i> (L.) Corr.	bael	Khan & Borle 1989; Viraktamath & Bhumannavar 2001	feeding (Khan & Borle)
<i>Aeglopsis chevalieri</i> Swingle	<i>Aeglopsis chevalieri</i> Swingle		Koizumi et al. 1996	survival for more than 5 weeks but no increase in numbers
<i>Afraegle gabonensis</i> (Swingle) Engl.	<i>Afraegle gabonensis</i> Engl.	Gabon powder-flask-fruit	Halbert & Manjunath 2004; Halbert pers. comm.	nymphs found in survey in Florida arboretum
<i>Afraegle paniculata</i> (Schumach. & Thonn.) Engl.	<i>Afraegle paniculata</i> (Schaum.) Engl.	Nigerian powder-flask-fruit, citron d'éléphant	Halbert & Manjunath 2004; Halbert pers. comm.	nymphs and eggs found in survey in Florida arboretum
<i>Atalantia buxifolia</i> (Poir.) Oliv.	<i>Atalantia buxifolia</i> (Poirot) D. Oliver	Chinese box-orange	Xu et al. (1988b)	survives and propagates normally
	<i>Severinia buxifolia</i> (Poirot) Ten.	Chinese box-orange	Koizumi et al. 1996; Hung et al. 2001; Halbert & Manjunath 2004; Halbert pers. comm.	survival for more than 7 weeks but no increase in numbers (Koizumi); normal development in the laboratory (Xu et al.); cited as suitable host (Hung et al.); damage evident, eggs, nymphs and adults observed in Florida surveys (Halbert & Manjunath)
<i>Atalantia monophylla</i> (L.) Corr. Serr.	<i>Atalantia monophylla</i> (L.) Corr.	Indian atalantia	Halbert & Manjunath 2004; Halbert pers. comm.	adult observed in survey in Florida arboretum
<i>Balsamocitrus dawei</i> Stapf	<i>Balsamocitrus dawei</i> Stapf.	Uganda powder-flask-fruit	Koizumi et al. 1996	survival for more than 7 weeks but no increase in numbers
<i>Citropsis articulata</i> (Spreng.) Swingle & M. Kellerman	<i>Citropsis schweinfurthii</i> (Engl.) Swingle & Kellerm.	West African cherry-orange	Capoor et al. 1967; Chavan & Summanwar 1993; Chavan 2004	abundant source (Capoor et al. 1967); good host (Chavan & Summanwar); completes development; moderate host (Chavan)
<i>Citropsis gilletiana</i> Swingle & M. Kellerman	<i>Citropsis gilletiana</i> Swingle & M. Kellerman	Gillet's cherry-orange	Halbert & Manjunath 2004; Halbert pers. comm.	eggs, nymphs and adults observed in survey in Florida arboretum; high populations prevented bud development
<i>Citrus amblycarpa</i> (Hassk.) Ochse	<i>amblycarpa</i> (Hassk.) Ochse (a possible hybrid)	nasnaran	Halbert pers. comm.	eggs observed in Florida arboretum survey
<i>Citrus australasica</i> F. Muell.	<i>Microcitrus australasica</i> (F.J. Muell.) Swingle	Australian finger-lime	Koizumi et al. 1996; Halbert & Manjunath 2004; Halbert pers. comm.	no multiplication, but adult survival for 5 weeks (Koizumi); damage evident, adults only present, in survey in Florida arboretum (Halbert & Manjunath)
	<i>Microcitrus australasiaca</i> (sic)	Australian finger-lime	Aubert 1987a, b, 1990a;	full development in laboratory (Aubert)
<i>Citrus australis</i> (Mudie) Planch.	<i>Microcitrus australis</i> (Planch.) Swingle	Australian round lime, dooja	Halbert & Manjunath 2004; halbert pers. comm.	damage evident, and eggs and nymphs observed, in survey in Florida arboretum
<i>Citrus cavaleriei</i> H. Lévêillé	<i>Citrus ichangensis</i> Swingle	Ichang (Yichang) papeda	Halbert pers. comm.	slight damage observed in

¹²⁹ Good photographs of some Australasian species, excluding those from New Caledonia, can be viewed on Mike Saalfeld's website (<http://www.saalfelds.freemove.co.uk/HobbyCitrusGrowers.htm>).

ex Cavalerie				Florida arboretum survey
<i>Citrus glauca</i> (Lindl.) Burkill	<i>Eremocitrus glauca</i> (Lindley) Swingle	Australian desert lime	Koizumi et al. 1996	variable adult survival but no multiplication and death after 4 weeks
<i>Citrus glauca</i> × <i>Shakura Citrus reticulata</i>	<i>Eremocitrus</i> hybrid		Halbert & Manjunath 2004; Halbert pers. comm.	eggs present and damage evident in survey in Florida arboretum
<i>Citrus hystrix</i> DC	<i>Citrus hystrix</i> DC.	leech lime, limau purut, limau hantu, kaffir lime, Mauritius papeda	Aubert 1987a, b, 1990a, 1992; Lim et al. 1989, 1990, Osman & Lim 1992	complete development and an occasional or common field host in Asia (Aubert); common (Lim et al. 1989, 1990); good field host in Malaysia (Osman & Lim 1992)
<i>Citrus inodora</i> F. M. Bailey		Russell River lime, large-leaf Australian wild lime	Halbert pers. comm.	slight damage in Florida arboretum survey
<i>Citrus japonica</i> Thunb.	<i>Fortunella crassifolia</i> Swingle	kumquat (Meiwa)	Halbert & Manjunath 2004; Halbert pers. comm.	good host, with eggs, nymphs and adults observed in survey in Florida arboretum
	<i>Fortunella hindsii</i> (Champ. ex Benth.) Swingle	Hong Kong kumquat	Halbert & Manjunath 2004, Li et al. 2007	some psyllid damage and some adults in Florida arboretum surveys (Halbert & Manjunath): host (Li et al.)
	<i>Fortunella japonica</i>		Li et al. 2007	host
	<i>Fortunella margarita</i> (Lour.) Swingle	kumquat	Halbert & Manjunath 2004; Halbert pers. comm.	nymphs in survey in Florida arboretum
	<i>Citrus japonica</i> Thunb.	kumquat	Halbert pers. comm.	few nymphs and adults with little damage in Florida arboretum
	<i>Fortunella polyandra</i> (Ridley) Tanaka	kumquat	Halbert & Manjunath 2004; Halbert pers. comm.	eggs, nymphs and adults observed in survey in Florida arboretum
	<i>Fortunella</i> sp.	kumquat	Aubert 1987a, b, 1990a	complete development in laboratory cage studies and an occasional field host in Asia
<i>Citrus maxima</i> (Burm.) Merr.	<i>Citrus decumana</i> L.	pomelo, pummelo	Husain & Nath 1927	attacked
	<i>Citrus grandis</i> (L.) Osbeck	pomelo, pummelo	Hoffmann 1936; Aubert 1987a, b; Rao & Pathak 2001	least most favoured of 6 hosts (Hoffmann); complete development and an occasional field host in Asia (Aubert); moderate incidence (Rao & Pathak)
	<i>Citrus maxima</i> (Burm.) Merr.	pomelo, pummelo	Catling 1968; Aubert 1990a	attacked (Catling); complete development and an occasional or common field host in Asia (Aubert)
	<i>Citrus obovoidea</i> Hort. ex Tanaka cv 'Kinkoji'	pomelo kinkoji	Halbert & Manjunath 2004	survey in Florida
<i>Citrus medica</i> L.	<i>Citrus medica</i> L.	citron	Aubert 1987a, b, 1990a; Rao & Pathak 2001	complete development and a common field host in Asia (Aubert); some on 'Gandharaj' (Rao & Pathak)
	<i>Citrus medica medica</i>	citron	Husain & Nath 1927	attacked
<i>Citrus reticulata</i> Blanco	<i>Citrus deliciosa</i> Tenore	mandarin	Aubert 1987a, b	complete development and a common field host in Asia
	<i>Citrus depressa</i> Hayata	flat lemon	Yasuda et al. 2005	host in Okinawa
	<i>Citrus nobilis</i> Loureiro	kam	Hoffmann 1936	third most favoured of 6 hosts

	<i>Citrus nobilis</i> Loureiro var. <i>deliciosa</i> (Ten.) Swingle ¹³⁰	kat	Hoffmann 1936	fourth most favoured of 6 hosts
	<i>Citrus reticulata</i> Blanco	mandarin	Aubert 1987a, b, 1990a; Catling 1968; Koizumi et al. 1996; Rao & Pathak 2001; Halbert & Manjunath 2004	complete development and a common field host in Asia (Aubert); attacked (Catling); survival for more than 7 weeks but no increase in numbers on 'Som-pan' (Koizumi); good on 'Khasi' (Rao & Pathak); common in surveys in Florida (Halbert & Manjunath)
<i>Citrus trifoliata</i> L.	<i>Poncirus trifoliata</i> (L.) Raf.	trifoliate orange	Aubert 1987a, b, 1990a, 1992; Koizumi et al. 1996	occasional host with oviposition but no nymphal development in laboratory cages (Aubert); survival for more than 7 weeks but no increase in numbers (Koizumi);
<i>Citrus wintersii</i> Mabb.	<i>Microcitrus papuana</i> H.F. Winters	Brown River finger lime	Halbert & Manjunath 2004; Halbert pers. comm.	damage evident, nymphs and adults observed, in survey in Florida arboretum
<i>Citrus</i> sp.	<i>Citrus limmettoides</i>	sweet lime	Rao & Pathak 2001	moderate
<i>Citrus</i> spp.	<i>Citrus</i> spp.		Kuwayama 1908; Crawford 1912, 1913; Miyatake 1965; Aubert 1990a; Viraktamath & Bhumannavar 2001; Halbert & Manjunath 2004	host (Kuwayama); common host (Crawford); uncommon host (Miyatake); common host (Aubert, Viraktamath & Bhumannavar, Halbert & Manjunath)
<i>Citrus × aurantiifolia</i> (Christm.) Swingle	<i>Citrus aurantiifolia</i> (Christm.) Swingle	lime, kagzi lime	Catling 1968; Aubert 1987a, b, 1990a; Rao & Pathak 2001; Halbert & Manjunath 2004; Halbert pers. comm.	attacked (Catling); complete development and a preferred field host in Asia (Aubert); zero population (Rao & Pathak); preferred host in Florida surveys (Halbert & Manjunath); heavy psyllid damage
	<i>Citrus pennivesiculata</i> (Lush.) Tanaka	moi		moderate damage in Florida arboretum survey
<i>Citrus × aurantium</i> L.	<i>Citrus aurantium</i> L.	sour orange, karun jamir	Rao & Pathak 2001	moderate (Rao & Pathak);
	<i>Citrus aurantium</i> L.	Chinotto	Halbert & Manjunath 2004; Halbert pers. comm.	eggs, nymphs and adults, with damage evident, in Florida surveys (Halbert & Manjunath)
	<i>Citrus maxima</i> var. <i>racemosa</i>		Aubert 1990	occasional in field, with complete development
	<i>Citrus nobilis</i> Lour.	not cited	Aubert 1987a, b	common
	<i>Citrus × nobilis</i> Lour.	not cited	Halbert & Manjunath 2004	common in Florida surveys (Halbert & Manjunath)
	<i>Citrus × paradisi</i> Macfad.	grapefruit	Aubert 1987a, b;; Tsai & Liu 2000; Halbert & Manjunath 2004	occasional in field, with complete development (Aubert), best host in laboratory (Tsai & Liu); common and a preferred host in Florida (Halbert & Manjunath)
	<i>Citrus sinensis</i> (L.) Osbeck	sweet orange (navel & Valencia); soh nariang	Husain & Nath 1927; Hoffmann 1936, Catling 1968; Aubert 1987a, b, 1990a; Rao & Pathak 2001; Halbert & Manjunath 2004	attacked (Husain & Nath); fifth most favoured of 6 hosts (Hoffmann); attacked (Catling); complete development and a common field host

¹³⁰ But possibly *C. × aurantium* 'King orange', often called, incorrectly, 'King mandarin'.

				in Asia (Aubert) moderate (Rao & Pathak); common in Florida surveys (Halbert & Manjunath)
	<i>Citrus sulcata</i> hort. ex I. Takahashi	sanbokan	Halbert pers. comm.	heavy psyllid damage in Florida arboretum survey
	<i>Citrus tamurana</i> hort. ex Tanaka	Hyuganatsu pomelo	Halbert pers. comm.	a host
<i>Citrus × junos</i> Siebold ex Tanaka (possibly a <i>C. cavaleriei</i> H. Léveillé ex Cavalerie (syn. <i>C. ichangensis</i> Swingle) × <i>Citrus reticulata</i> Blanco hybrid)		yuzu	Halbert pers. comm.	some psyllid damage in Florida arboretum survey
<i>Citrus × limon</i> (L.) Osbeck	<i>Citrus assamensis</i> S. Dutta & S.C. Bhattach.	adajamir	Rao & Pathak 2001	good host
	<i>Citrus limon</i> (L.) Burm. f.	lemon	Catling 1968; Aubert 1987a, b; 1990a	attacked (Catling); complete development and a common field host in Asia (Aubert)
	<i>Citrus limonia</i> Osbeck	lemon	Hoffmann 1936	first most favoured of 6 hosts (Hoffmann)
	<i>Citrus medica</i> var. <i>acida</i> Hook. f.	sour lime, khatta	Husain & Nath 1927	attacked
	<i>Citrus medica</i> var. <i>limetta</i>	sweet lime, mitha	Husain & Nath 1927	attacked
	<i>Citrus medica</i> var. <i>limonum</i> Hook. f.	lemon, limu	Husain & Nath 1927	attacked
	<i>Citrus meyeri</i> U. Tan	Meyer lemon	Halbert & Manjunath 2004	survey in Florida
<i>Citrus × microcarpa</i> Bunge	<i>Citrus madurensis</i> Lour.	calamondin	Aubert 1990a; Osman & Lim 1992	complete development and a common host plant in Malaysia (Aubert; Osman & Lim)
<i>Citrus × taitensis</i> Risso	<i>Citrus jambhiri</i> Lushington	rough lemon; east (Estes?) rough lemon	Rao & Pathak 2001; Halbert & Manjunath 2004	some to moderate (Rao & Pathak); surveys in Florida (Halbert & Manjunath)
<i>Citrus × virgata</i> Mabb.	<i>Microcitrus</i> sp. 'Sydney'	Sydney hybrid	Halbert & Manjunath 2004; Halbert pers. comm.	damage evident, eggs and nymphs observed, in survey in Florida arboretum
<i>Limonia acidissima</i> L.	<i>Limonia acidissima</i> L.	Indian wood apple, elephant apple, wood apple	Khan & Borle 1989; Koizumi et al. 1996; Hung et al. 2000	all stages present (Khan & Borle); marked increase in populations (Koizumi); suitable host (Hung)
<i>Merrillia caloxylon</i> (Ridley) Swingle	<i>Merrillia caloxylon</i> (Ridley) Swingle	kamuning, katinga, ketengah, Malay lemon	Lim et al. 1990a,b	cage in laboratory (Lim et al.)
<i>Murraya paniculata</i> (L.) Jack (<i>sensu lato</i>)	<i>Murraya exotica</i> L. ¹³¹	jasmine orange, orange-jessamine	Catling 1968; Khan & Borle 1989; Aubert 1990a, Koizumi et al. 1996; Yasuda et al. 2005	breeding field populations in the Philippines (Catling); all stages present on 'Kunti or China box' (Khan & Borle) adult feeding in laboratory cages (Aubert); marked increases in populations (Koizumi); a preferred host in southern China (Beattie pers. observation, Guangzhou, 2006) where, probably erroneously, only ' <i>M. paniculata</i> ' has been reported as a host (see Yang et al. 2006); a host in

¹³¹ As noted previously, the common cultivated ornamental form of orange jasmine is considered to be *Murraya paniculata* (L.) Jack var. *exotica* (*sensu* Huang), unless otherwise stated. The status of the species is complex and resolution of this uncertainty is the objective of a PhD being undertaken at the University of Western Sydney by Nguyen Huy Chung.

<i>Murraya paniculata</i> (L.) Jack		jasmine orange, orange-jessamine	Maki 1915; Kuwayama 1931; He (= Hoffmann) & Zhou 1935; Miyatake 1965; Cheema & Kapur 1975; Singh & Nimbalkar 1977; Catling et al. 1978; Tirtawidjaja 1981; Aubert & Quilici 1984; Tsai et al. 1984; Aubert 1987a, b, 1990a; Osman & Lim 1992; Koizumi et al. 1996; Tsai et al. 2000, 2002; Halbert & Manjunath 2004	Okinawa (Yasuda et al.) enumerated as one of the food-plants in Tawian (Maki, Kuwayama); noted as an alternative host (He & Zhou); many nymphs and adults observed on plants over several years (Miyatake); new host (Cheema & Kapur); preferred host (Singh & Nimbalkar); all stages frequently observed in Bangladesh (Catling et al.); vector in transmission studies (Tirtawidjaja); favourable host on 'green hedge plant' (Tsai et al.); suitable host in Reunion with up to 11 generations in a laboratory and 10 in the field (Aubert & Quilici); complete development and a preferred field host in Asia (Aubert); all stages (Osman & Lim); marked in increase in populations (Koizumi); host on which most abundant (Tsai et al. 2000); present in all seasons in Florida (Tsai et al. 2002); preferred host in Florida surveys (Halbert & Manjunath)
<i>Naringi crenulata</i> (Roxb.) Nicolson	<i>Naringi crenulata</i> (Roxb.) Nicolson	hesperethusa	Halbert & Manjunath 2004; Halbert pers. comm.	heavy infestation in survey in Florida arboretum
<i>Pamburus missionis</i> (Wight) Swingle	<i>Atalantia missionis</i> (Wall. ex Wight) Oliv. <i>Pamburus missionis</i> (Wall. ex Wight) Swingle		Tirtawidjaja 1981	successful feeding and transmission
<i>Swinglea glutinosa</i> (Blanco) Merr.	<i>Swinglea glutinosa</i> <i>Swinglea glutinosa</i> (Blanco) Merr.	tabog tabog	Aubert 1990a; Waterhouse 1998 Tirtawidjaja 1981; Halbert & Manjunath 2004; Halbert pers. comm.; ACIAR/UWS/UGM field observations	eggs, nymphs and adults observed in survey in Florida arboretum feeding in laboratory cage studies successful feeding and transmission (Tirtawidjaja); damage evident, eggs and nymphs observed, in Florida surveys (Halbert & Manjunath); feeding, oviposition and development (ACIAR/UWS/UGM)
<i>Triphasia trifolia</i> (Burm. f.) P. Wilson	<i>Triphasia trifoliata</i>	limeberry, triphasia	Aubert 1987a, b, 1990a; Osman & Quilici 1991; Koizumi et al. 1996; Waterhouse 1998	complete development in laboratory cage studies and an occasional field host in Asia (Aubert); complete development in cage studies (Osman & Quilici); no increase in populations but survival for 5 weeks (Koizumi et al.)
	<i>Triphasia trifolia</i> (Burm. f.) P. Wilson	limeberry, triphasia	Aubert 1987a; Koizumi et al. 1996; Halbert & Manjunath 2004; Halbert pers. comm.	occasional host (Aubert), adult survival for several weeks but no increase in numbers (Koizumi et al.); adults plentiful, all stages present, and damage evident in Florida surveys (Halbert & Manjunath)

Uncertain (possibly a species or species of <i>Atalantia</i> , <i>Citrus</i> , <i>Pamburus</i>)	<i>Atalantia</i> sp.	Koizumi et al. 1996; Aubert 1978 a, b, 1990a; 1992	marked increase in populations (Koizumi); adult feeding but oviposition and development not known (Aubert) — record based on comments by Zhao Xueyuan as reported by Barkley et al. (1979)

Table 2. Known Aurantioideae: Clauseneae species on which the Asiatic citrus psyllid, *Diaphorina citri*, has been observed to rest, feed or complete its development.

Species or hybrid	Cited as	Common name	Original citations	Summary of observations
<i>Bergera koenigii</i> L.	<i>Murraya euchrestifolia</i> Hayata	curry leaf	Hung et al. 2000	suitable host
	<i>Murraya koenigii</i> (L.) Spreng.	curry leaf	Fletcher 1917, 1919; Husain & Nath 1927; Chakraborty et al. 1976; Singh & Nimbalkar 1977; Aubert 1987a, b,, 1990a; Osman & Lim 1989; 1990; 1992; Osman & Quilici 1991; Lim et al. 1990a; Chavan & Summanwar 1993; Koizumi et al. 1996; Halbert & Manjunath 2004	alternative food plant (Fletcher; Husain & Nath); when given a choice all adult psyllids migrated from citrus seedlings to curry leaf seedlings on which successful breeding colonies were established and maintained (Chakraborty et al.); preferred host (Singh & Nimbalkar) variable host with no or limited development (Aubert 1987a, b); a good host (Aubert 1990a); an important alternative host (Osman & Lim); an important alternative host (Lim et al.); good population growth (Osman & Quilici); infests and breeds throughout the year (Chavan & Summanwar); some increase in population (Koizumi); not an excellent host in Florida surveys but will support a small population (Halbert & Manjunath)
<i>Clausena anisumolens</i> Merrill	<i>Clausena anisum-olens</i> Merrill	kayumanis (Tagalog)	Gavarra & Mercado 1988; Aubert 1990a	feeding, and seemingly more attractive than <i>M. paniculata</i> , but no oviposition in cage tests (Gavarra & Mercado 1988; Aubert 1990a)
<i>Clausena excavata</i> Burm f.	<i>Clausena excavata</i> Burm. f.		Aubert 1990a; Lim et al. 1990a; Osman & Lim 1992	complete development (Aubert); important alternative host (Lim et al.; Osman & Lim)
<i>Clausena indica</i> Oliv.	<i>Clausena indica</i> Oliver		Tirtawidjaja 1981	a successful feeding and transmission (Tirtawidjaja)
<i>Clausena lansium</i> (Lour.) Skeels	<i>Clausena lansium</i> (Lour.) Skeels	wong p'ei, wampee, huangpi	Hoffmann 1936, Xu et al. 1988b; Koizumi et al. 1996; Aubert 1990a; Halbert & Manjunath 2004; Halbert pers. comm.	second most favoured of 6 hosts (Hoffmann); survives and propagates normally (Xu et al.); variable adult survival but no multiplication (Koizumi et al.); complete development and a common field host in Asia (Aubert); eggs, nymphs and adults with

populations highly variable in Florida surveys (Halbert & Manjunath; Halbert pers. comm.)

Table 3. Known species of Rutoideae on which the Asiatic citrus psyllid, *Diaphorina citri*, has been observed to rest, feed or complete its development.

Species or hybrid	Cited as	Common name	Original citations	Summary of observations
<i>Ravenia spectabilis</i> (Lindl.) Planch. ex Grisbeg. (syn. <i>Lemonia spectabilis</i> Lindl.)			Richard Lee and Susan Halbert (pers. comm., November 2008)	adults relatively easy to find on plants in Fairchild Botanic Gardens, Miami, Florida
<i>Tetradium ruticarpum</i> (A. Juss.) T. G. Hartley ¹³²	<i>Evodia rutaecarpa</i> (A. Juss.) Benth.	evodia, wu zhu yu	He (2000) cited by Yang et al. (2006)	Record not verified and <i>Evodia</i> misspelt as <i>Euodia</i>
<i>Toddalia asiatica</i> (L.) Lamarck	<i>Toddalia asiatica</i> (L.) Lam.	orange-climber, forest pepper	Aubert 1987a, b, 1990a, 1992	feeding but no oviposition in cage studies
<i>Vepris lanceolata</i> (Lam.) G. Don	<i>Vepris lanceolata</i> G. Don	white ironwood	Aubert 1987a, b, 1990a, 1992	feeding but no oviposition in cage studies
<i>Zanthoxylum fagara</i> (L.) Sarg.	<i>Zanthoxylum fagara</i> (L.) Sarg.	lime prickly-ash	Halbert & Manjunath 2004	plenty of suitable new shoots in Florida arboretum survey; very few <i>D. citri</i> found; possible non-host.

¹³² Inoue et al. (2006) recorded *Psylla evodiae* Miyatake feeding on *M. paniculata* in Japan, noting that it also occurs on *Tetradium glabrifolium* (Champ. ex Benth.) T. G. Hartley (cited as *Euodia meliifolia* (Hance) Benth.) and feeds on '*Zanthoxylum beechyanum* var. *alatum* (Nakai) Hara'.

Appendix VII: Hosts of *T. erytrae*

Table 1. Known Aurantioideae: Aurantieae species and varieties on which the African citrus psyllid, *Trioza erytrae*, has been observed to rest, feed or complete its development¹³³.

Species or hybrid	Cited as	Common name	Original citations	Summary of observations
<i>Citrus australasica</i> F. Mueller	<i>Microcitrus australasiaca</i> (sic)	desert lime	Aubert 1987a, b	feeding
<i>Citrus japonica</i> Thunberg	<i>Fortunella</i> sp.	cumquat, kumquat	Aubert 1987a, b	feeding and oviposition
<i>Citrus maxima</i> (Burm.) Merr.	<i>Citrus grandis</i>	pomelo, pummelo	Aubert 1987a, b	common host with occasional complete development
<i>Citrus medica</i> L.		citron	Aubert 1987a, b	preferred host with complete development
<i>Citrus reticulata</i> Blanco	<i>Citrus deliciosa</i>	mandarin	Aubert 1987a, b	common host with complete development
	<i>Citrus nobilis</i>	mandarin	Aubert 1987a, b	common host with complete development
	<i>Citrus reticulata</i>	mandarin	Aubert 1987a, b	common host with complete development
<i>Citrus trifoliata</i> L.	<i>Poncirus trifoliata</i> (L.) Raf.	trifoliata orange	Aubert 1987a, b	feeding
<i>Citrus × aurantiifolia</i> (Christm.) Swingle	<i>Citrus aurantiifolia</i>	lime	Aubert 1987a, b	preferred host with complete development
<i>C. × aurantium</i> L.	<i>Citrus sinensis</i>	sweet orange	Aubert 1987a, b	common host with complete development
	<i>Citrus paradisi</i>	grapefruit	Aubert 1987a, b	common host with complete development
<i>Citrus × limon</i> (L.) Osbeck	<i>Citrus limon</i>	lemon	Aubert 1987a, b	preferred host with complete development
	<i>Citrus limon</i>	lemon	Moran 1968	complete development with 89.5% completion
<i>Murraya paniculata</i> (L.) Jack	<i>Murraya exotica</i> L.		van der Merwe 1941	attacked to slight extent
	<i>Murraya paniculata</i>	jasmine orange, orange-jessamine	Aubert 1987a, b	common host with occasional complete development
<i>Triphasia trifolia</i> (Burm. f.) P. Wilson	<i>Triphasia aurantiola</i> Lour.		van der Merwe 1941	attacked to slight extent

Table 2. Known Aurantioideae: Clauseneae species on which the African citrus psyllid, *Trioza erytrae*, has been observed to rest, feed or complete its development.

Species or hybrid	Cited as	Common name	Original citations	Summary of observations
<i>Clausena anisata</i> (Willd.) Hook. f. ex Benth. ¹³⁴	<i>Clausena anisata</i> (Willd.) Hook. f. ex Benth.	horsewood, maggot killer	van der Merwe 1941; Moran 1968; Aubert 1987a, b	cited as host in Belgian Congo and possibly identical to <i>Clausena inaequalis</i> (van der Merwe); 64% of individuals completed development and possible original host (Moran, Aubert 1987a, b) *
	<i>Clausena inaequalis</i> (DC.) Benth.),	horsewood, maggot killer	van der Merwe 1941	most favoured of possible original food plants*

¹³³ Good photographs of some Australasian species, excluding those from New Caledonia, can be viewed on Mike Saalfeld's website (<http://www.saalfelds.freereserve.co.uk/HobbyCitrusGrowers.htm>).

¹³⁴ Molino (1994) considered *Cl. anisata* to be a 'recent' introduction to Africa from Asia.

Table 3. Known species of Rutoideae on which the African citrus psyllid, *Trioza erytreae*, has been observed to rest, feed or complete its development¹³⁵.

Species or hybrid	Cited as	Common name	Original citations	Summary of observations
<i>Calodendrum capense</i> (L. f.) Thunb.	<i>Calodendron capense</i>	Cape chestnut	van der Merwe 1941; Moran 1968, Aubert 1987a, b	no possible for insects to live upon (van der Merwe); entirely unsuitable (Moran); feeding (Aubert)
	<i>Calodendrum capense</i> (L. f.) Thunb.	Cape chestnut	Moran 1968	feeding, oviposition, instar development with no completions
<i>Toddalia asiatica</i> (L.) Lamarck	<i>Toddalia asiatica</i>	orange-climber, forest pepper	Aubert 1987a, b	feeding and oviposition
<i>Vepris</i> sp.	<i>Oricia</i> sp.		Catling 1973	galls observed on leaves
<i>Vepris lanceolata</i> (Lam.) G. Don ¹³⁶	<i>Toddalia lanceolata</i> Lam.		van der Merwe 1941	probably among original food plants (van der Merwe)
	<i>Vepris lanceolata</i>	white ironwood	Aubert 1987a, b	preferred host with complete development (Aubert)
	<i>Vepris undulata</i> (Thunb.) Verdon & Smith	white ironwood	Moran 1968	best host with 90.1% development
<i>Zanthoxylum capense</i> (Thunb.) Harv.	<i>Fagara capense</i>	small knobwood	Moran 1968; Aubert 1987a, b	less suitable than <i>V. lanceolata</i> and <i>Cl. anisata</i> but still adequate and (Moran 1968); common host with weak complete development (Aubert)
	<i>Fagara capensis</i> Thunb.	small knobwood	van der Merwe 1941, Moran 1968	among original food plants (van der Merwe), complete development with 40% completion; was almost as suitable as a host as <i>C. × limon</i> (Moran)

van den Berg & Deacon (1989) observed adult *T. erytreae* in feeding positions for many hours of the day, and therefore presumably feeding, on *Casimiroa edulis* L & L. [Rutaceae], *Heferomorpha arborescens* (Spreng.) Cham. & Schlecht. [Umbelliferae] and *Trichilia emetica* Vahl (syn. *Trichilia roka* Chiov. [Meliaceae]. These plants were far from the citrus trees and between other plants, and were not suitable for nymphal development. They also caught adult *T. erytreae* after dark on these three species (*Ca. edulis*, *H. arborescens* and *Tri. emetica* Vahl) and on *Nephrolepis exaltata* (L.) Schott (Pteridophyta: Polypodiaceae), *Cinnamomum verum* J. Presl, *Persea americana* Mill. [Lauraceae] [Lauraceae], *Breonadia microcephala* (Del.) Hiern (Rubiaceae), *Hibiscus* sp. [Malvaceae], *Pimenta dioica* (L.) Merr., *Syncarpia* sp., and *Syzygium cordatum* Hochst. ex Krauss [Myrtaceae].

¹³⁵ Observations reported by Evers & Grisoni (1991), and reports by Temu & Andrew (2008) and Burgess et al (2002), suggest that two other species of *Vepris*, *V. mildbraediana* G.M. Schulze (of uncertain taxonomic status: Mziray 1992) and *V. morogorensis* var *subulata* (Kokwaro) W. Mziray, may be also be hosts of *T. erytreae*, and possible '*Ca. L. africanus*' in Morogoro, Tanzania.

¹³⁶ *Boscia undulata* Thunb. and *V. querimbensis* Klotzsch are also synonyms of *V. lanceolata* (see Mziray 1992). For additional information see <http://www.aluka.org/action/showMetadata?doi=10.5555/AL.AP.FLORA.FZ1261&pgs=>.

Appendix VIII. Origins of *D. citri* and *T. erytrae*

D. citri

Modern psyllids, including the Diaphorininae and Triozinae, probably evolved with the Sapindales in Gondwana (Hollis 1985, 1987, White & Hodkinson 1985). The Diaphorininae have an ecological preference for dry climates (Hollis 1987). *D. citri* was first recorded as a serious pest of citrus in India by Husain & Nath (1927) who, in describing the damage it caused, were the first to describe what are now known to be symptoms of huanglongbing. In the early to mid 1930s, *D. citri* did not assume such a destructive status in China, the Philippines, Malaya or Indonesia (Clausen 1933, Hoffmann 1936). Hoffmann and Clausen were both aware of the destruction wrought by the psyllid in India (Hoffmann 1936). Husain & Nath (1927) described damage caused they believed to be solely caused by *D. citri* as follows: ‘... *D. citri* neither produces galls nor causes any malformation of the plant tissues. The only sign of injury is defoliation and death of the shoots attacked and the drying up of the branches. On badly infested trees the continual feeding of myriads of insects is, in itself, a very great drain on the food-supply of the plant, but most probably some poison is also injected into tissues of the host and this produces the more serious results. This is evident from the fact that the fruit of the infested tree is dry and insipid to taste, and branches other than those actually attacked also dry up. Besides, young shoots are killed, old leaves fall off and in course of time an attacked tree is denuded of leaves altogether’ ‘During the second year of attack, if the pest has been allowed to develop unchecked, all the new shoots are destroyed, and most of the branches are left without leaves and the tree begins to dry up. Very little fruit is borne and that too is of small size, insipid and dry.’

All evidence supports the views of Hollis (1987) and Halbert & Manjunath (2004) who suggested, that the *D. citri* evolved in India in association with a species of *Murraya*¹³⁷: within the subtribe Clauseneae as circumscribed by Swingle & Reece (1967)¹³⁸. Which species of *Murraya*, is an issue that needs to be resolved in light of the recent morphological, phytochemical (But et al. 1986) and molecular studies (Samuel et al. 2001, Bayer et al. 2009) that are discussed below. Although orange jasmine, *Murraya paniculata* (L.) Jack, is generally regarded as the preferred host of *D. citri*, it was not reported as a host of the psyllid in India until 1975 (Cheema & Kapur 1975), 60, 41 and 13 years respectively after it was reported as a host in Taiwan by (Maki 1915, Kuwayama 1931), in China by He & Zhou (1935), and in the Ryukyu Islands of Japan by (Miyatake 1965). Oddly, *B. koenigii* (cited as *M. koenigii*) was the first *Citrus* relative to be recorded as host of the psyllid in India (Fletcher 1917, 1919, Husain & Nath 1927).

D. citri was described from Taiwan (Kuwayama 1908). Crawford (1919) recorded it as being present in the Philippines, Taiwan, Java, Malay Archipelago, Bengal, southern India and southern China, and noted that Frederick Muir collected specimens from Macao and Amboina (Moluccas) in 1906. Clausen (1933) recorded it as being present in China, the Philippine Islands, Taiwan, Malaya, Dutch East Indies, Burma, India, and Ceylon. We have not been able to verify the records for Macau and Ambon, and Hoffmann (1936) regarded detection of *D. citri* in Guangdong in 1934 as the first record of the psyllid in China. If it was present in China, it cannot have been widespread: Hoffmann commenced his studies on pests of citrus and other plants in Guangdong in 1926 (Jiang et al. 1935). Further evidence that the psyllid was not present in China before 1930 is provided by Luh (1936) who, in a paper on factors, including pests and diseases, causing fruit loss in 1935 in Zhejiang, did not mention the presence of *D. citri* or symptoms resembling huanglongbing.

¹³⁷ In 1987 the genus *Murraya*, as circumscribed by Swingle & Reece (1967), fell within the tribe Clauseneae. Some species, including orange jasmine (*M. paniculata* (L.) Jack), which is considered to be the favoured host of *D. citri*, have been recently transferred to the Aurantieae [Citreae] (Samuel et al. 2001, Bayer et al. submitted). Others, including the curry plant (*Bergera koenigii* L. = Swingle's *M. koenigii*) remain within the Clauseneae.

¹³⁸ The assumption of Tsai & Liu (2000) and Tsai et al. (2002) that *D. citri* evolved in the Far East appears to be based on misinterpretation of distribution records cited by Mead (1977).

Information about two primary parasitoids of *D. citri* also suggests that the psyllid evolved in India. Both parasitoids were first described from India, the ectoparasitoid *Tamarixia radiata* (Waterston) [Hymenoptera: Eulophidae] by Waterston (1922), and the endoparasitoid *Diaphorencyrtus aligarhensis* (Shafee, Alam & Agarwal) [Hymenoptera: Encyrtidae] by Shafee et al. (1975). Most records of *T. radiata*¹³⁹ in Southeast Asia appear to be related to intentional introductions (Chien et al. 1988, Chiu et al. 1988, Waterhouse 1998) whereas, records of *D. aligarhensis*¹⁴⁰ appear to be linked to unintentional movement of parasitised *D. citri* nymphs on live plants to Taiwan (possibly before 1900) and the Philippines, and to natural spread overland with its host. *D. aligarhensis* is not, as assumed by Chien et al. (1988, 1989, 1991), native to Taiwan or the Philippines. No parasitoids were associated with *D. citri* populations when the psyllid was first recorded in Guangzhou (Hoffmann 1936). Tang (1988) mentioned the introduction of *T. radiata* to Fujian in China, but considered it as possibly indigenous, given its wide distribution in Fujian, as recorded in surveys within four years of its introduction. He also considered it possible that the parasitoid occurred in Taiwan before it was released there (Tang 1988) and indigenous in Asia, from Saudi Arabia to China (Tang 1990). This is not supported by other records. An encyrtid with a yellow abdomen (presumably *D. aligarhensis*) was present in the Philippines in 1968, but *T. radiata* was not (Catling 1968): it was introduced in 1988 (Gavarra & Mercado 1988, Gavarra et al. 1990) and the encyrtid with the yellow abdomen was identified as *D. aligarhensis* (Gavarra & Mercado 1988). Both parasitoids were present in Java in Indonesia in 1987 (Nurhadi 1987). Based on comments by Nurhadi (1988) it seems they may have been introduced to Indonesia on psyllid infested plants. In addition to *D. citri*, hosts of *D. aligarhensis* apparently include *Diaphorina cardiae* Crawford), *Diaphorina auberti* Hollis and *Psylla* sp. (Tang & Aubert 1990: *Diaphorina cardiae* is a junior synonym of *Diaphorina aegyptiaca* Puton (Bürkhardt 1984).

T. erytreae

T. erytreae is native to sub-Saharan Africa (Hollis 1984). It is the only species of *Trioza* that is known to feed and develop on Rutaceae (Hollis 1984, Aubert 1987) (see Appendix VII) and belongs to a complex of species that are difficult to define morphologically but which have discrete host plant preferences (Hollis 1984)¹⁴¹. It has two native rutaceous hosts in Africa on which it can complete its development, *V. lanceolata* and *Z. capense* (Moran 1968, Hollis 1984, Aubert 1987). It also feeds on the native monospecific *Calodendrum capense*, but cannot complete its life cycle on this species (Moran 1968). Synonyms of *V. lanceolata* include *Boscia undulata* Thunb., *Toddalia lanceolata* Lam, *Vepris querimbensis* Klotzsch and *Vepris undulata* (Thunb.) Verdoorn & CA Smith (see Mziray 1992). (*Z. capense* is often cited as *Fagara capensis* Thunb., and sometimes as *F. capense*). Non-native African hosts on which *T. erytreae* can complete its development in Africa include *Citrus* species and hybrids, *M. paniculata* and the *Cl. anisata* (syn. *Cl. inaequalis* (DC.) Benth.) (Moran 1968, Hollis 1984, Aubert 1987). *Cl. anisata* species is often stated as being native to Africa (e.g., Moran 1968, Aubert 1987, OEPP/EPPO 2005b) and is host of the *Ca. L. africanus* (Korsten et. al. 1996). It is, however, native to the Western Ghats of India and the northeast part of the Indian subcontinent through to China and has a plethora of synonyms too long to list here (see Molino 1994). Although *Cl. anisata* is the second-most favourable non-citrus host of *T. erytreae* in Africa (Moran 1968), there does not appear to any report of *D. citri* feeding or developing on it in Asia. The fact that *V. lanceolata* is the preferred native host of *T. erytreae* in Africa (Moran 1968) suggests that it is the original host of this psyllid. However, observations reported by Evers & Grisoni (1991), and reports by Temu & Andrew (2008) and Burgess et al. (2002), suggest that two

¹³⁹ syns *Tetrastichus radiatus* Waterston (Waterston 1922, Graham 1969, Tang 1990, Tang & Aubert 1990, Waterhouse 1998) and *Tetrastichus indicus* Khan & Shafee (Hayat & Shahi 2004).

¹⁴⁰ syns *Aphidencyrtus aligarhensis* Shafee, Alam & Agarwal, *Aphidencyrtus diaphorinae* Myartsera & Tryapitzyn and *Psyllaephagus diaphorinae* Lin & Tao (Noyes & Hayat 1984, Prinsloo 1985, Tang 1990, Tang & Aubert 1990, Waterhouse 1998).

¹⁴¹ A second species of *Trioza*, *T. litseae* Bordage (syn. *T. eastopi* Orian) has been recorded feeding occasionally on *Citrus* (Aubert & Quilici 1984, Aubert 1987).

other species of *Vepris*, *V. mildbraediana* G.M. Schulze and *V. morogorensis* var *subalata* (Kokwaro) W. Mziray, may be also be hosts of *T. erythrae*, and possibly ‘*Ca. L. africanus*’ in Morogoro, Tanzania.

Version 2

Appendix IX: Nomenclature, systematics and general biology of the Psylloidea

Psylloids, commonly known as jumping plant-lice or lerps, include at least 2500 but probably more than 3000 species worldwide (Gullan & Martin 2003). Although 'psyllid' is widely used to refer to members of the superfamily Psylloidea its use causes confusion as it is often used sloppily, alluding both to the entire superfamily as well as the family Psyllidae. The correct term is 'psylloid' (Gullan & Martin 2003). They ingest sap from a variety of tissue sources, including phloem, xylem, and mesophyll parenchyma, and thus are not phloem specialists like most other sternorrhynchs (Gullan & Martin 2003). Six families are recognised: Calophyidae, Carsidaridae, Homotomidae, Phacopteronidae, Psyllidae and Triozidae. All six families are represented in Australia, although the former four are only poorly (White & Hodkinson 1985).

The Psylloidea are generally highly host specific and mostly associated with dicotyledonous angiosperms. Reproduction is normally sexual and sex ratios usually approximate 1:1. Eggs are laid singly or in clusters on suitable hosts. Eggs are usually deposited with their pedicel inserted into host tissue through which eggs obtain moisture, although some are inserted beneath the leaf epidermis. Eggs inserted into leaf tissue that subsequently dies fail to hatch. There are five larval instars, and there may be from one to many generations per year, dependent upon climatic conditions and phenology of hosts. The effects of feeding activity may vary from little visual effect to necrosis around feeding sites, early senescence of leaves, leaf distortion and defoliation, leaf galling, die-back of young growth and death of the host. Generalist predators of the Psylloidea include birds, spiders, ants, coccinellid beetles, syrphid and lace-wing larvae, and mirid and anthocorid bugs. Encyrtid and eulophid wasps are the main larval parasitoids (Gullan & Martin 2003, Kristoffersen 2003).

Reviews of psylloid biology were presented by Hodkinson (1974, 1986) and Gullan & Martin (2003). Information about egg structure is given by Taylor (1992). Keys to families are presented in Brown & Hodkinson (1988) for the Neotropics; Burckhardt & Mifsud (1998) for the Arabian Peninsula; Morgan (1984) for South Australia; and, Taylor & Carver (1991) for Australia.

Appendix X: Biology and ecology of *D. citri* and *T. erytreae*

Diaphorina citri

Aubert (1988a, 1990b), in summarising the then known distribution of *D. citri*, regarded it as a surprisingly enduring insect capable of surviving a wide range of temperatures extremes, from 45°C in Saudi Arabia to -7° or 8°C in subtropical China.

Several authors have reported observations and results of experiments on the biology and ecology of *D. citri*, in field studies and under insectary and laboratory conditions, the latter generally superficial and meaningless, as the impact of one key environmental factor, saturation deficit (an interaction between ambient temperatures and humidity), on the psyllid and its hosts seems to have been overlooked. In contrast to studies on *T. erytreae*, impacts of saturation deficit on *D. citri* have not been adequately assessed—despite observations that the *D. citri* is better adapted to regions with high saturation deficits (high temperatures and low relative humidities¹⁴²) and not to regions with low saturation deficits (medium to high temperatures and high relative humidity). Here we summarise the results of field studies, then insectary and laboratory studies.

Orchard and field cage studies

Catling (1970a) summarised key biological and morphological differences between *D. citri* and *T. erytreae*. These differences are summarised in Table 1, and illustrated in Fig. 1.

Table 1. Key biological and morphological differences between *D. citri* and *T. erytreae* (after Catling 1970a)

Life cycle stage(s)		<i>Diaphorina citri</i>	<i>Trioza erytreae</i>
Egg			
location		on tips of growing shoots, on and between unfurling leaves	mostly along edges of young leaves
placement on plant tissue		long axis vertical to surface	long axis horizontal to surface
Nymphs			
location		mainly on young stem and petioles	on lamina of underside of leaves
appearance	colour	yellowish brown	variable: yellowish orange, light green, grey
	abdominal spots	no abdominal spots	advanced nymphs with two dark abdominal spots
	sclerites	well-defined sclerites on dorsum	no definite plates or sclerites
	wing pads	massive wing pads	small wing pads
	fringe	large filaments on abdomen only	complete fringe of fine white filaments
	leaf galls	no gall formed, nymphs completely exposed	open gall or pit formed, only dorsal surface of nymph exposed
Adults			
appearance	colour	general colour light brown	overall brown-grey, abdomen lighter ventrally
	wings	head mainly light brown with dark areas (maculate)	head black
			clear and transparent

¹⁴² High, medium and low are relative terms, but the context in which they are used is widely understood.

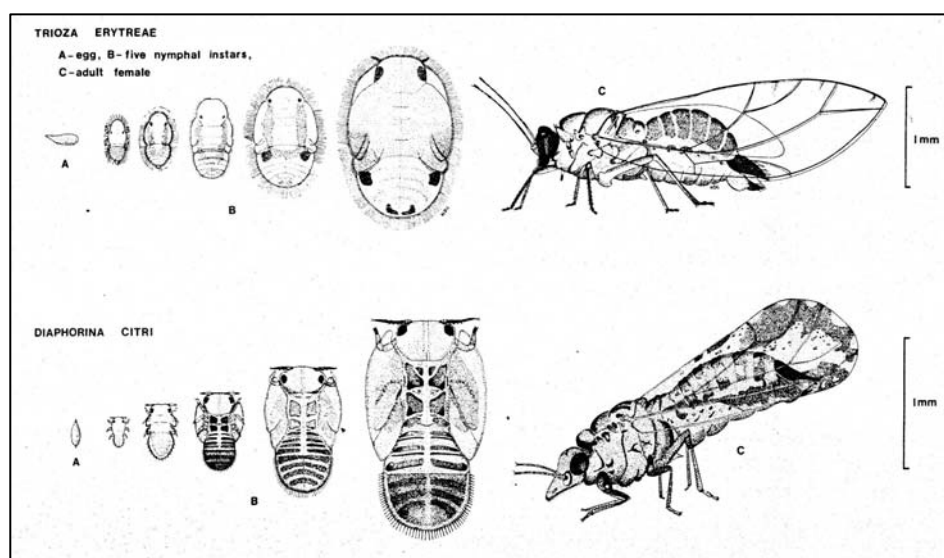


Figure 1. Key biological and morphological differences between *D. citri* and *T. erytreae* (after Catling 1970a).

The first detailed observations on the biology, ecology and control of *D. citri* were published by Husain & Nath (1927), who studied details of its structure, life history, bionomics and control in the laboratory and under field conditions over 6 years in the Punjab in pre-partitioned India¹⁴³. They regarded *D. citri* as the most serious pest of citrus in India noting that it was present all over the country. It was so abundant in many localities as to call special attention, and caused serious losses in certain tracts in the region. In one instance, an orchard leased for 2000 rupee per year yielded no more than 100 rupee after an attack lasting a couple of years. They mentioned that it was not an uncommon site to see once valuable orchards reduced to unproductive plantations of dried skeletons of trees, primarily through the ravages of *D. citri*.¹⁴⁴

They (Husain & Nath 1927) noted that the adults copulated soon after eclosion¹⁴⁵ and observed that ‘As the genital segments of the male are turned upwards the male has to approach the female from the side and bend the tip of its abdomen down to the level of the aperture of the female genitalia; thus a male may be seen in that position holding the female with the legs of one side and supporting itself with the legs of the other side, the heads resting in the same position.’

They observed that after copulation the female laid eggs if tender shoots¹⁴⁶ were available, and that ‘The eggs are always laid on fresh growth, usually in the folds of half-opened leaves, axils of leaves, pushed in between the buds and stem or petioles of leaves and auxillary buds, an other situations. They are also laid scattered about on the upper or lower surfaces of the leaves and on tender stem. It may be stated that the females do not lay eggs on older tough leaves or stems even in the absence of tender shoots. The stalk is thrust into the tissue of the plant and the egg is firmly in position. In some case, however, particularly when too many eggs have been laid at the bottom of a folded or half-opened leaf, a few eggs appear to lie loose, simply glued on to the surface of the leaf.’

The younger stages of the five nymphal instars ‘are mostly concealed, and are found at the tips of tender shoots. During the later stages they move down the shoot. They do not however, leave the fresh shoot and are never found on the last season’s growth. When disturbed they move about in a slow, steady manner. They can withdraw their long mouth-parts and re-thrust them into the plant tissue readily.’

¹⁴³ India was partitioned into two independent nations in 1947. The Punjab now falls within both countries.

¹⁴⁴ And what we now recognise as HLB, based on the descriptions of Husain & Nath (1927).

¹⁴⁵ Newly eclosed adult *D. citri* are whitish with lacy and transparent wings that gradually assume their normal adult colour in about 2 hours (Bigornia & Obana 1974).

¹⁴⁶ The pedicel of the egg is inserted into the soft flush growth of hosts. It, as for all psylloids, helps to maintain a supply of water to developing eggs (White 1968, Hollis 2004), which fail to hatch if the tissue in which they are laid dies (White 1968, Catling 1971). Mangat (1961) reported that 266 to 700 eggs are laid, depending on ambient temperatures during daylight hours the availability of tender shoots, singly, in groups, or in clusters, as well as in single, double and triple straight lines. Mangat & Singh (1960) observed females mating immediately after mating.

In field studies in involving the use of sleeve cages on small citrus plants grown in pots in orchards at Faisalabad (formerly Lyallapur: 30°35' N, 74°73', 300 m asl), in the Punjab region of modern-day Pakistan, they noted that 'a female may lay over 800 eggs, and continue to lay eggs for about two months¹⁴⁷ during spring (March-May), and that the egg stage lasted '4 to 6 days in summer and up to 22 days in winter'. The total duration of five nymphal instars from 11 to 25 days according to the season, with each instar lasting about 3 days in summer, and the first, and the second to fifth instars, lasting 11 to 12 days, and 4 days respectively in winter (Husain & Nath 1927). The total life cycle occupied 15 to 45 days depending on the season, and adults were observed to live for as long as 189 days (Husain & Nath 1927). There were 9 generations per year. There was considerable overlapping of generations and no definite broods were recognised. No hibernation was observed, but females that eclosed in late summer (August) did not lay eggs for one month (until October, mid autumn) and those that emerged in October did not lay eggs for over 3 months. This was attributed to the absence of suitable young shoots for oviposition. The authors (Husain & Nath 1927) predicted that that an additional 2-3 generations would have occurred (11-12 generations per year) had suitable young growth been present. Mean monthly minimum and maximum temperature records for Faisalabad (183 m asl) are presented in Table 2¹⁴⁸.

Table 2. Mean monthly minimum and maximum temperatures in Faisalabad¹⁴⁹.

Month	Maximum °C	Minimum °C
January	19.4	4.1
February	21.9	7.1
March	26.7	12.3
April	33.5	18
May	38.4	22.7
June	40.5	26.9
July	37.1	27.1
August	36.1	26.6
September	35.7	23.7
October	33	17
November	27.2	10.1
December	21.4	5.1

Atwal et al. (1970) reported that *D. citri* can have up to 16 generations in the eastern portion of the Punjab region of India and Pakistan, with a single generation over 77 days in winter (December to February) and the shortest being 13.8-14.4 days in spring (April-May) and from mid summer (August) to early autumn (mid-October). They noted that extremes of both high and low temperatures were harmful to the pest, with sub-zero temperatures being more important in suppressing upsurges in populations in spring. Mild winters followed by favourable springs provided suitable conditions for high populations. Heaviest damage occurred during flowering in spring. They (Atwal et al. 1970) also noted that 90.8%, 98 and 100% of nymphs on new flush growth were found within 5 cm, 10 cm and 15 cm of the tip of the growth.

Lin et al. (1973) observed and 8 or 9 generations of *D. citri* a year in field studies at Wufeng (24° 02' N, 120° 38' E, 85 m asl) in central Taiwan. Adult females laid eggs on the buds when trees sprouted. At high densities of nymphs, buds dried and died or developed abnormal foliage. In the

¹⁴⁷ Pande (1971) recorded 180-520 eggs per female on citrus twigs. Huang (1990) reported that maximum fecundity was near 1900 eggs, averaging 630-1230. On orange jasmine Liu & Tsai (2000) recorded maximum fecundity of 748 eggs at 28°C. Tsai & Liu (2000) recorded means of 858, 626, 572 and 612, and maxima of 1378, 830, 818 and 994 respectively on grapefruit, orange jasmine, rough lemon and sour orange seedlings under laboratory conditions.

¹⁴⁸ <http://www.statpak.gov.pk/depts/fbs/publications/yearbook2007/climate/3.3.pdf>

¹⁴⁹ <http://www.statpak.gov.pk/depts/fbs/publications/yearbook2007/climate/3.3.pdf>

absence of buds adults stayed under the leaf blade. Production of buds as a result of typhoon damage or irregular pruning favoured development of psyllid populations.

Pande (1972) observed that eggs, nymphs and adults of *D. citri* were found throughout the year on six citrus varieties from July 1965 to June 1966 in orchards at Udaipur (27° 42' N, 75° 33' E, about 600 m asl) in Rajasthan, India. Pest activity increased in February (late winter) with the appearance of tender foliage. Populations peaked during March-April (spring). With the onset of summer, populations decreased, with adults being the most abundant life cycle stage, before increasing from July and peaking again in August, then decreasing again to reach their lowest point from November to January when adults were again the most abundant life cycle stage. Pande (1972) also ranked host preference, noting that in August 1965, the psyllid was most abundant on citron (330/15 cm twig), then, in order of decreasing abundance, sweet orange (210), sweet lime (170), grapefruit (140), pomelo (137) and lemon (70). He concluded that varieties with succulent leaves were more susceptible, while those with thick and coarse leaves were less susceptible.

Bigornia & Obana (1974) reported the seasonal incidence of all life cycle stages over 2-3 years from 1969-1971 on unsprayed 12 year-old mandarin and calamondin trees at Guinobatan (12° 30' N, 123° 22' E; 120 m asl) in southern highlands of Albay Province, about 500 km south of Manila, in the Philippines. This region has a climate with no definite dry and wet seasons, and rainfall is distributed more or less evenly throughout the year. Egg peaks occurred in May and October, and numbers were lowest in August and December. Adult populations peaked twice annually, in June (mid summer) and September. Lower densities occurred in July/August and again from October to December, declined in July and August. Two severe typhoons¹⁵⁰ in October 1970 led to almost complete disappearance of *D. citri* populations for almost 5 months and disruption of population trends (Bigornia & Obana 1974).

Koli et al. (1981) studied the seasonal incidence of several citrus pests on unsprayed 'citrus' trees near Shrirampur (19° 37' N, 74°38' E; about 1000 m asl) in the state of Maharashtra in western peninsular India from 1974-1977. They observed that the incidence of *D. citri* was at 'rock bottom level' during the period from November onwards to January (late autumn to mid winter). This was followed by a slight build up in February and a peak in March (spring). The population then declined gradually until June before increasing again in July, peaking in August, and then declining again. The absence of an anticipated third peak in October was attributed to exceptionally low incidence of suitable flush growth. Average ambient temperatures during periods of flush growth in February/March, July/August and October were 28°C, 24°C and 27°C. Relative humidity was high in July/August and low in February.

Khan et al. (1984) concluded that at Nagpur (21° 09' N, 79° 09' E, 312 asl), some about 1,100 km west of Mumbai (Bombay) in Maharashtra, the activity of *D. citri* on orange trees was synchronised with sprouting of new shoots. During spring (February-April), when trees had abundant new flush, high populations of eggs and nymphs were observed. Numbers of eggs and nymphs appeared to increase with increasing temperature and decreased with increase in rainfall, as well as relative humidity during the late summer wet (monsoon) season. They noted that populations diminished when relative humidity exceeded 89%: 'by this time only a few scattered eggs and nymphs were noticed wherever new shoots were present'. Weather data cited by the authors (Khan et al. 1984) are summarised in Table 3.

¹⁵⁰ Super typhoons 'Joan' and 'Kate': [http://en.wikipedia.org/wiki/Typhoon_Joan_\(1970\)](http://en.wikipedia.org/wiki/Typhoon_Joan_(1970))

Table 3. Weather data (rounded) cited by Khan et al. (1984) for Nagpur, Maharashtra, India.

Month	min-max °C	min-max %RH	mL rain
February	15-32	37-75	60
June	27-39	33-52	63
July	24-31	70-84	383
September	24-31	71-89	349
December	16-27	48-78	102

Aubert (1987c) reported that *D. citri* is commonly found from sea level to 1500 m asl in the south-western Arabian Peninsular. Maximum summer temperatures at 1500 m ranged from 32-34°C and minimum temperatures in winter were as low as 2.5°C. The psyllid was absent in orchards above 1700-1800 m asl where occasional frosts occur (Aubert 1987c).

Xie et al. (1988) studied cold endurance of *D. citri* in Zhejiang, in coastal east China, as part of research undertaken in response to spread of HLB into southern regions of the province following accidental introduction of the vector some 10-15 years earlier. Their purpose was to determine boundaries for northern expansion of *D. citri* and to gain information to tighten quarantine measures. They conducted experiments in which the psyllid was exposed to temperatures below freezing in refrigerators, cold stores, and in field cages during winter. They found that adults can survive low temperatures that are lethal for citrus but long periods (> 100 h) at -2° and -5°C were more detrimental than lower temperatures for shorter intervals. The results of the field experiment are summarised in Table 4. The authors also summarised meteorological factors affecting the distribution of *D. citri* in Zhejiang, separating the province into regions where the psyllid was common (well colonised, below 28° N and coastal), present low levels (lightly colonised, below 28° 20' N and coastal to mid-inland), likely to occur in future (possible, inland below 28° N and coastal from 27.50° N to 29.30° N), and unlikely to occur (psyllid-free area, above 29° 40' N). This information is presented in Table 5. The northern most distribution of *D. citri* is now at Tiantai (29° 08' N, 121° 01' E) (Wang et al. 2003). This is in the area Xie et al. (1988) regarded as possibly suitable for the psyllid.

Table 4. Percent mortality of adult *D. citri* over 3-10 days during winter at Shixiang, 840 m asl in Wencheng County (ca. 27° 50' N, 120° 00' E), in Zhejiang, China (Xie et al. 1988).

Interval	Average daily temperature (°C)	Average lowest temperature (°C)	Lowest temperature (°C)	Number of adults	% mortality
27-31 December 1983	-3.0	-4.5	-10.1	160	55.0
30 December 1983-1 January 1984	-4.9	-8.5	-10.1	122	71.3
11-20 December 1984	6.9	4.2	-2.5	473	1.1
22-30 December 1984	-2.8	-7.3	-10.5	468	81.4

Huang et al. (1990) observed that psyllid populations in orchards increased from mid March (mid-spring), reaching the highest density in late April (late spring) and early May (early summer). The peak lasted 2-3 months depending on environmental factors. Psyllid fluctuations were mainly influenced by the flushing rhythm of citrus trees.

Chavan & Summawar (1993) noted that fluctuations in psyllid populations in Maharashtra in India were more related to flushes of growth on host plants than to weather extremes, and that populations increased quickly when conditions were favourable.

Zhu (1993) proposed that 6.4°C, the minimum monthly mean daily temperature over 20 consecutive years, should be used as the winter limiting factor instead of mean daily temperature exceeding 10°C and the minimum temperature over years (see Yang et al. 2006). Zhu (1993) used isotherms

based on the index of minimum monthly mean temperatures to divide Jiangxi into three zones: most suitable, slightly suitable and potentially spreading, with the temperature index mentioned above 7.5°C, 6.4°C to 7.4°C and 5.4°C to 6.3°C respectively.

Table 5. Climate summaries of counties in Zhejiang considered suitable for sustaining populations of *D. citri* and those considered as possibly suitable or unsuitable by Xie et al. (1988).

Counties	Suitability for <i>D. citri</i>	Average temperature (°C) in January	Lowest temperature (°C)	Days below		
				0°C	-5°C	-10°C
Pingyang, Qingtian & Ruian	Suitable for medium to heavy populations ('well colonised')	7.3 to 8.1	-3.2 to -5.0	7.7 to 15	0.1 to 1	0
Taishun, Lishui & Yunhe	Suitable for 'light' populations	5.0 to 6.7	-6.6 to -13.1	22.2 to 37.8	0.8 to 6.1	0 to 0.1
Huangyan, Yuang, Longquan, Xiangshan & Shengxian	'Possibly' suitable	5.4 to 6.9	-5.3 to -7.5	8.0 to 25.5	0.1 to 2.7	0
Hangzhou, Huzhou & Jiaxing	Not suitable ('psyllid-free')	2.7 to 4.3	-9.8 to -17.4	> 40	> 4.4	0.1 to 0.3

Zhu (1993) proposed that 6.4°C, the minimum monthly mean daily temperature over 20 consecutive years, should be used as the winter limiting factor instead of mean daily temperature exceeding 10°C and the minimum temperature over years (see Yang et al. 2006). Zhu (1993) used isotherms based on the index of minimum monthly mean temperatures to divide Jiangxi into three zones: most suitable, slightly suitable and potentially spreading, with the temperature index mentioned above 7.5°C, 6.4°C to 7.4°C and 5.4°C to 6.3°C respectively.

Quan et al. (1998) found that *D. citri* could over-winter in northern Guangxi (circa 25° N and northwards, and > 150 m asl) when the mean daily temperature in January exceeded 6.3°C. In Guangdong, frosts can significantly reduce over-wintering populations, more so than cold weather with no frosts, and limit the size of spring populations (Liao 1999). In the absence of frosts citrus trees in Guangdong are also able to produce new growth in winter and spring growth occurs sooner than it would if frosts occur (Liao 1999). In the coldest regions where *D. citri* occurs in China only adults over-winter (Yang et al. 2006).

Ashihara (2007) investigated survival of *D. citri* adults during winter in Tsukuba (36° 4' N, 140° 7' E), about 50 km northwest of Tokyo in Japan. Adult populations on a potted Satsuma mandarin tree in a screened field-cage did not decline rapidly during an interval when daily minimum temperatures decreased below 0°C for 4 days and during which the temperature fell to -3.9°C. However, adults died rapidly over the next 12 days when daily minimum temperatures were continuously below 0°C and the lowest minimum temperature reached -6.4°C. When adults maintained at 15°C were transferred in mid to late winter they did not die immediately, even though the minimum temperature fell to below -4°C on the first and third days. In laboratory studies, adults survived for 50 days on orange jasmine plants held at constant temperatures of 12.5 and 15°C. The author concluded that the psyllid would survive winters in areas where mean daily minimum and maximum temperatures of the coldest month are above 5° and 12.5°C respectively. In an earlier study (Ashihara 2004), the author concluded, from field experiments, that the psyllid would survive in winters in parts¹⁵¹ of Kyushu in southern Japan under conditions where minimum temperatures exceed -3.3°C.

Chavan (2004) noted that *D. citri* completed its life cycle in 26.75 d, 29.75 d, 30.75 d and 33.00 d respectively on *C. × aurantiifolia*, *C. × aurantium* (Mosambi sweet orange), *Citropsis articulata*

¹⁵¹ Makurazaki (31° 15' N, 130° 20' E, 30 m asl), Akune (32° 01' N, 130° 12', 40 m asl) and Kuchinotsu (32° 36' N, 130° 11' E, 10 m asl).

and *B. koenigii* respectively at Pune (Poona: 18° 31' N, 73° 55' E) about 560 m asl and some 160 km southeast of Mumbai in Maharashtra, India.

Fig. 2 shows *D. citri* adults and eggs on a citrus tree in the Malakand Valley (34° 40' N, 71° 55' E, 670 m asl), North West Frontier Province, Pakistan, on 17 July 2006. It was 47°C. Maximum daily temperatures in this region often exceed 45°C from late spring to early autumn, peaking between 48°C and 50°C from May (late spring) and August (late summer). Average daily relative humidity at 15:00 during May is 28%, and 25%, 38% and 45% respectively in June, July and August. The insect, contrary to laboratory results reported by Tsai & Liu (2000), appears to thrive under these conditions when leaves on irrigated host plants are turgid. This suggests that survival of the psyllid is related to evaporative cooling of leaves, and of psyllid nymphs and adults. Leaf temperatures under such conditions may be several degrees below those at lower ambient temperatures and higher relative humidity (see Gates 2003). Although evaporative cooling by psyllids has not been recorded, it has for other insects (Prange 1996).



Figure 2. Adult Asiatic citrus psyllids on eggs on lemon flush growth at the orchard at Palai, Malakand, 17 July 2006 (GAC Beattie).

Laboratory and insectary studies

Mangat & Singh (1960) reported that adult pairs remained in coitus for about 7 to 22 min, presumably over a range of ambient temperatures. Mangat (1961) reported that eggs are laid during daylight hours singly, in groups, or in clusters, as well as in single, double and triple straight lines. Mean numbers of eggs laid by females ranged from about 266 to 700, depending on ambient temperatures, and the availability of tender shoots. Eggs hatched in 3 to 12 d and nymphal development took 9.5 to about 36 d under similar conditions.

Catling (1968, 1970a) reported observations from the Philippines that were in general agreement with those reported by Husain & Nath (1927).

Khan et al. (1989) reported studies on the biology of *D. citri* on 'potted jamberry plants (Fam: Rutaceae)' under room conditions in an insectary in Maharashtra, India. They reported on mating, courtship behaviour, copulation, oviposition, the eggs, egg hatch, the nymphs and the adults, the life cycle and number of generations under the prevailing conditions. They compared their observations with those reported by Husain & Nath (1927), Atwal (1962) and Pande (1971). As there is no other

record of 'jamerry' being used common name for a species of Rutaceae we could not determine the identity of the plants used in the study. However, it is possible that the cultivar was rough lemon, *C. × taitensis* Risso (= *C. × jambhiri* Lush.).

Liu & Tsai (2000) studied development, survival, longevity, reproduction, and life table parameters of *D. citri* at 10°C, 15°C, 20°C, 25°C, 28°C, 30°C and 33°C in growth chambers at 75-80% RH. Populations reared at 10°C and 33°C failed to develop. Between 15°C and 30°C, the mean developmental period from egg to adult varied from 49.3 d at 15°C to 14.1 d at 28°C. The low-temperature developmental thresholds for first through to the fifth instars were estimated at 11.7°C, 10.7°C, 10.1°C, 10.5°C and 10.9°C, respectively. Survival rates of third, fourth and fifth instars between 15°C and 28°C were similar. The mean longevity of females increased with decreasing temperature within 15°C and 30°C. The maximal longevity of individual females was recorded 117, 60, 56, 52 and 51 days at 15°C, 20°C, 25°C, 28°C and 30°C, respectively. The average number of eggs produced per female significantly increased with increasing temperature, reaching a maximum of 748 eggs at 28°C. The optimum range of temperatures for *D. citri* population growth was 25°C to 28°C, and at 28°C the shortest population doubling time (3.5 d) and mean generation time (28.6 d).

Tsai & Liu (2000) studied the biology of the citrus psyllid *D. citri* at 25°C on orange jasmine, grapefruit, rough lemon and sour orange in the laboratory. The average egg incubation periods varied very little (4.1 to 4.2 days). The average nymphal developmental periods were essentially the same except the fifth instar. Survival rates of nymphs on orange jasmine, grapefruit, rough lemon and sour orange were 75.4%, 84.6%, 78.3%, and 68.6% respectively. Female adults lived an average of 39.7 d, 39.7 d, 47.6 d, and 43.7 d respectively on these hosts. The average number of eggs laid per female on grapefruit (858 eggs) was significantly more than those laid on the other hosts. Mean population generation times on the hosts ranged from 31.6 d to 34.1 days.

McFarland & Hoy (2001) assessed survival of adult *D. citri* in the absence of food or water at 7%, 33%, 53%, 75% and 97% RH at both 25°C and 30°C. The LT₅₀s at the lower temperature were 24.9 h, 28.3 h, 28.5 h, 37 h, and 43.2 h respectively. At the higher temperature, the values were 12.1 h, 18.0 h, 20.4 h, 23.2 h, and 32.2 h respectively.

Nakata (2006) predicted that the northern limit for survival of populations in southern Japan may be about 31°N, off the southern shores of Kyushu Islands. This prediction was based on regression equations derived for development of eggs, nymphs (first to fifth instar) and eggs to adults against temperature, for temperatures ranging from 15°C to 32.5°C under a 16L:8D regime. There was no mortality of first to fourth instar nymphs at 15°C, but nymphs held at this temperature failed to develop to adults due to 100% mortality of fifth instar nymphs. There was no mortality of nymphs reared at 17.5°C, 20°C, 22.5°C, 25°C, 27.5°C and 30°C, but mortality of third, fourth and fifth instars held at 32.5°C was 26.7, 43.3 and 83.3% respectively. The lower temperature development threshold and thermal constant values for (a) the egg were 13.66°C and 46.93 degree-days (°D), for (b) the nymphs (first to fifth instars inclusive) 11.56°C and 192.27 °D, and (c) for egg to adult 12.16°C and 232.26 °D.

Nava et al. (2007) determined rates of development of *D. citri* on orange jasmine, Rangpur lime and a mandarin in laboratory studies. The durations of development on the immature stages on the three hosts were similar, but nymphal viability on mandarin was lower than on the lime and orange jasmine, and these were the better hosts. Duration of the egg and nymphal stages varied from 2.6 d to 7.7 d, and from 9.4 to 35.8 days, respectively, at temperatures ranging from 18°C to 32°C. Nymphal viability at 32°C was dramatically lower than at the lower temperatures. The lower temperature development threshold and thermal constant values for (a) the egg were 12°C and 52.6 dd, for (b) the nymphs (first to fifth instars inclusive) 13.9°C and 156.9 °D, and (c) for egg to adult 13.5°C and 210.9 °D.

Summary

The following is a brief summary of the studies on the biology and ecology of *D. citri*.

- the potential for populations to exist and flourish declines with increasing altitude and latitude (both vary with region) with low altitudes (< 800 m asl depending on region, with a preference for lower altitudes) and high saturation deficits (warm to very hot climates with low relative humidity) preferred to high altitudes and low saturation deficits (warm to hot climates with high relative humidity) (see Aubert 1987c, 1990b, Yang et al. 2006);
- tolerance of low ambient temperatures (e.g., mid winter average daily temperatures between 5.4°C to 6.9°C, with minimums from -5.3°C to -7.5°C (Xia et al. 1988)
- tolerance of temperatures as high as 50°C (Husain & Nath 1927);
- Husain & Nath (1927) reported total life-cycle lengths of 15-47 d, depending on season;
- impacts of climate on adult longevity vary and adults can live for up to 6 to 9 months (Husain & Nath 1927, Xie et al. 1989) in regions with cool to cold winters;
- annual generations depend on regional climates: in the Punjab, Husain & Nath (1927) reported 9, but predicted 11-12 in the presence of suitable flush growth, Atwal et al. (1970) reported 16, and in China, Yang et al. (2006) reported 6-11 depending on the region where observations were made;
- the host range is mostly within the Aurantioideae with a preference, for *M. paniculata/exotica* and *Citrus* (see Appendix VI);
- host preference is influenced by season, variety, flush morphology, abundance, frequency and duration of flushing;
- psyllid populations can increase rapidly, particularly in spring when the N content of usually abundant flush growth is high and when competition between females for flush growth is low (Atwal et al. 1970, Catling 1971, Pande 1972, Koli et al. 1981, Khan et al. 1984, Huang et al. 1990, Hung 2008);
- *D. citri* reproduces sexually (Husain & Nath 1927);
- the sex ratio is approximately 1:1: Catling (1968, 1970b) reported a sex ratio of 1.23♀:1♂;
- adults mate shortly after eclosion from the fifth and final nymphal instar (Husain & Nath 1927);
- females may produce up to 1900 eggs: Husain & Nath (1927) recorded up to 807 per female, Pande (1971) recorded 180-520 females on citrus twigs, Huang (1990) reported that maximum fecundity was near 1900 eggs, averaging 630–1230, Liu & Tsai (2000) recorded maximum fecundity of 748 eggs at 28°C on orange jasmine, and Tsai & Liu (2000) recorded means of 858, 626, 572 and 612, and maxima of 1378, 830, 818 and 994 respectively on grapefruit, orange jasmine, rough lemon and sour orange seedlings under laboratory conditions;
- females lay their eggs in the growing tips of young host plants, preferring flush growth < 6 mm in length to longer flush lengths: numbers of eggs laid on a flush decline rapidly as the length of flush increases, and when individual leaves attain lengths > 10 mm, and flushes 50 mm (Lin et al. 1973, Chen & Liao 1982, Leong 2006);
- numbers of eggs laid per leaf are greatest on the first leaf, and then progressively lower on the second and subsequent leaves (Xu et al. 1994);
- unfertilised eggs do not hatch;
- the psyllid has five nymphal instars with no diapause;
- nymphs are free-living (they do not form galls);
- oviposition preferences reflect the need for the five nymphal instars of the psyllid to complete their development on immature growth; most eggs are laid within 14 d of new growth commencing (Lin et al. 1973);

- initiation of oogenesis, and subsequent maturation of eggs within ovaries, is closely related to the presence of buds (Dai et al. 1982, Huang 1990, Huang et al. 1999) and breeding activity is largely suspended when citrus trees are dormant (Waterhouse 1998); and
- flight is limited generally to a few metres where hosts are abundant, and possibly limited to 0.5-2 km when searching for a host; dispersal over 90 to 470 km is, or may be, possible in strong winds, such as those associated with cyclones (Aubert & Xia 1990, Sakamaki 2006, Gottwald et al. 2007, Halbert et al. 2008).

Trioza erytreae

Field

McClea & Oberholzer (1965a) reported the first positive transmission of HLB by an insect vector, in this instance *T. erytreae*, from infected to healthy sweet orange trees.

Schwarz (1967) found a convincing correlation between the incidence of HLB and the activity of *T. erytreae* in South Africa. The disease was particularly severe in the cool, moist upland citrus areas where the vector is commonly abundant. Very little greening and no natural spread of the disease was found in the Transvaal Lowveld (now Mpumalanga) and the Eastern and Western Cape where populations of *T. erytreae* are low and isolated.

Catling (1969b) found that **extreme weather** in the eastern Transvaal (Mpumalanga) and Swaziland in southern Africa played a predominant role in regulating populations of *T. erytreae* by inducing, through desiccation, heavy mortality in the developmental stages of the psyllid. Populations were consistently highest in the cool, moist upland region (up to 1280 m asl) of each study district and were always low and isolated in the hot, arid lowlands (none occurred at 503 m asl). There was a trend for higher populations to develop in mild seasons or following spells of cool, overcast weather during the summer months. *In situ* counts revealed that all stages of *T. erytreae* are sensitive to high temperature combined with low relative humidity. The eggs and first instars were found to be considerably more vulnerable to these extremes than the more advanced stages. A correlation analysis for egg to first instar survival showed that maximum daily saturation deficit, and maximum daily temperature combined with vapour pressure were both highly significant and convenient predictors of mortality. Catling (1969b) gave a regression equation for survival against the mean saturation deficit for the three severest days during the egg and first instar stages. He showed that, because of the occurrence of distinct field generations and the extreme sensitivity of the young stages, actual mortality depended largely on the age distribution in the population. Frequency and timing of daily saturation deficits above 3.453 kPa¹⁵² were found valuable in explaining differences in population densities.

Green & Catling (1971) subsequently defined a **saturation deficit index (SDI)** for the purpose of assessing the regional weather-induced mortality of *T. erytreae* in southern Africa. They based the SDI on a regression curve, which reliably depicted the combined effects of temperature and humidity on the mortality of eggs and first instar nymphs in the field. The regression clearly explained the known geographic distribution of *T. erytreae*. The furthest and most frequent incursions of the SDI into the lethal range (by definition above 3.46 kPa¹⁵³ or 70% mortality) occurred in the low-lying Malelane area of Mpumalanga (then Eastern Transvaal). They noted that at 26° S in southern Africa, SDI values frequently enter the lethal range for approximately 8 months of the year at 150 m asl, but only for 2.5 months at 700 m asl. The longer the duration of lethal conditions, the more improbable it was for the vulnerable egg to first instar stages, which at regular

¹⁵² 25.9 mm Hg

¹⁵³ 34.6 mbar.

intervals form the bulk of the population, to escape heavy mortality. Although low altitudes were generally associated with high SDI values this was not so for summer rainfall areas such as Rustenburg (25° 40' S 27° 15' E, 1,157 m asl) where lethal SDI values could occur for up to 7 months annually. Impacts were also related to the timing of lethal-range SDI values. In some districts under the summer rainfall conditions, values peaked in spring and early summer during a period when growth flushes are vigorous and frequent and *T. erytrae* potentially abundant. When lethal conditions were confined mainly to this period, *T. erytrae* populations were considered to be well-established in the area. The authors (Green & Catling 1971) noted that although short periods of lethal weather could cause heavy mortality of egg and first instar nymphs of a large spring population, the survivors, together with the more resistant stages, were capable of bridging short gaps between flushes and producing a substantial population recovery. In any citrus area with repeated association of lethal SDI values with periods of low flush density, especially in the latter half of summer, the psyllid would be likely to be scarce.

Catling (1971) reported the impacts of **host plant quality** on *T. erytrae* populations. He observed that nymphs underwent prolonged development on poorly nourished citrus leaves, with poor condition in the field causing high rates of mortality and occurrence of flattened nymphs of reduced size. *In situ* counts indicated that nymphal survival decrease, with an increase in leaf size (age). There was also a tendency for progressively higher survival toward the apex of the flush point, regardless of leaf size. He (Catling 1971) stated that, despite the presence of amino acids in the excreta, leaf protein (measured as N) is critical in the nutrition of *T. erytrae*. Nymphal development appeared to be severely affected when the N content fell below 2%, though he considered such low levels as not common in well managed citrus groves. The N content of young flush was found to decline with age, and that in the flush of seedlings and young trees was higher than in the flush of mature trees. Of greater significance was the seasonal fluctuation in the N content of young flush, highest levels (above 4% nitrogen) being recorded in spring and early summer when *T. erytrae* populations multiply rapidly, and lowest levels (below 2.5% N) occurring in the winter growth. He assumed that the protein content of foliage largely controls the fecundity of adult *T. erytrae* females¹⁵⁴.

Catling (1973) summarised the **life history** of *T. erytrae* in the field and under insectary conditions. The incubation period in the field varied from 6-15 d and nymphal development from 17-43 d, both being strongly correlated with mean temperature. Pre-oviposition was usually 3-5 d in summer (mean temperature 24°C-26°C) and 6-7 d in winter (14°C-16°C) and longevity 17-50 d depending on season (shorter in summer, longer in winter). Sex ratios fluctuated in the field but females were always predominant. He (Catling 1973) noted that adults mate several times and that under insectary conditions **mated females laid 217-1305 eggs** whereas unmated females laid fewer eggs which were infertile. Mating takes place as soon as the teneral adult hardens and occurs at all times of the day. It is initiated, sometimes aggressively, by the male. A mating pair align themselves in parallel both facing in the same direction and remain *in coitu* for about four minutes. In the insectary, two females were observed to mate an average of 2-3 times a day during a six day period while others mated 3-4 times a day. Longevity appeared to be similar for both sexes. The threshold temperature for nymphal development was probably between 10°C and 12°C. He (Catling 1973) also said that although field observations revealed a small but definite movement of adults away from citrus, *T. erytrae* did not appear to possess strong dispersal powers.

McClean (1974) reported observations that indicated that the number of adult *T. erytrae* carrying the African HLB pathogen was relatively small in relation to the total adult population found on trees in South Africa in a region where the incidence of the disease was high. He reported evidence seasonal fluctuations in the number of carriers: more occurring among adults emerging from the summer flushes on citrus trees, and few, if any, among those emerging during winter and early

¹⁵⁴ These observations may explain why *D. citri* populations also peak in spring.

spring. However, he noted that the efficiency of the vector was not seriously impaired by the small number of carriers; it was offset by the large numbers of adults that emerged during favourable conditions, thus insuring spread of the disease to many healthy trees, and to healthy sectors of partially diseased trees. There was no evidence that the causal organism of greening is passed through eggs laid by infective adults. McClean (1974) also observed that attempts to infect psylla experimentally by feeding them on diseased sources succeeded only very occasionally. In contrast, adults collected off diseased trees in the field were always more effective in transmitting the disease.

van den Berg & Deacon (1988) studied **dispersal** of the *T. erytreae* by releasing about 25,000 adults in a ploughed land of 3 × 2.5 km and recapturing them with yellow sticky traps. Even in the absence of their host plants, they were able to disperse, with the aid of prevailing winds, at least 1.5 km. More females than males were captured at distances beyond 500 m. They estimated that the maximum lifespan of adults in the absence of host plants was 85.37 h, and ascribed death under such circumstances to desiccation, rather than starvation. van den Berg & Deacon (1989) found that most **flight activity** of *T. erytreae* in summer and autumn in an 8-year old citrus orchard occurred in two peaks, the first between 10:00 and 11:00 and the second, and larger peak shortly before sunset, when host searching occurred. No flight activity was recorded at night when adults could be found on host and non-host plants.

van den Berg et al. (1991b) observed continuous **movement of *T. erytreae* adults** between an unsprayed¹⁵⁵, but well maintained, 2 ha, 8-year old citrus orchard¹⁵⁶ comprising grapefruit, navel, ortanique and Valencia varieties, and adjacent indigenous vegetation. The latter, an area of 3 ha, was situated 15-25 m to the north-east and south-west of the citrus orchard, and extended for a further 2 km to the north-east. This vegetation comprised *Cl. anisata*¹⁵⁷, *V. lanceolata* and *Z. capense*¹⁵⁸ scattered under the shade of larger trees. van den Berg et al. (1991b) concluded:

- that psyllid populations increased more rapidly in indigenous vegetation than in citrus during July, September and October, when populations in the orchard were low;
- that when populations in the citrus orchard rose in November and peaked in December, populations in the indigenous vegetation declined to small numbers and, on the basis of these observations;
- that populations of *T. erytreae* would be higher in citrus orchards near indigenous host plants than in orchards separated from indigenous vegetation¹⁵⁹.

van den Berg et al. (1991a) observed that *T. erytreae* adults **dispersed** more frequently as numbers of eggs, nymphs or adults on the citrus increased (positive correlations), and when flush growth declined (negative correlation).

Evers & Grisoni (1991) classified prevalence of HLB in Tanzania into four zones: (a) located in highlands above 1200 m asl, with a high degree of HLB; (b) 800-1200 m asl, with fairly high populations of *T. erytreae* but moderate symptoms of HLB; (c) 500-800 m asl, as an intermediate zone with very light infection and relatively small vector populations; and (d) below 400m, a zone with no psyllids and no natural spread of the disease. They attributed this gradient to temperature sensitivity of the pathogen and increasing vector mortality of under warm and dry conditions, noting that eggs and first instars are extremely vulnerable to temperatures above 25°C. Field observations showed that 100% mortality of eggs and first instar nymphs occurred at maximum

¹⁵⁵ For 5 years.

¹⁵⁶ At Nelspruit (25° 27' S, 30° 59' E, 670 m asl) in Mpumalanga, South Africa.

¹⁵⁷ A host of *T. erytreae* but one now considered to be introduced from Asia and not indigenous to Africa: see Molino (1994).

¹⁵⁸ These plants do not occur in Australia.

¹⁵⁹ Presumably, based on van den Berg & Deacon (1988), at least several kilometres apart.

saturation deficit (msd^{160}) of ≥ 45 mbars; 70% mortality occurred at 35 mbars and 10% at 15 mbars. The two major citrus production areas in Tanzania were located in the low risk area. The authors noted that the Uluguru Mountains, rising to 3000 m asl, were a reservoir for psyllids invading orchards at Sokoine Agricultural University (570 m asl) at Morogoro ($6^\circ 26' \text{ S}$, $37^\circ 32' \text{ E}$).

Laboratory and insectary studies

The sensitivity of *T. erytrae* to high temperatures was first reported by van der Merwe (1923, 1941) and was later shown under laboratory conditions by Moran & Blowers (1967). Blowers & Moran (1967) reported that high temperatures (8 h at 32°C per day) inhibited egg-laying and ovarian development of *T. erytrae* under laboratory conditions. They observed that in insects succumbing to high temperatures, the mycetome shifted from its normal position in the egg and underwent colour changes in adults and eggs. However, Catling (1969b) noted that studies in an insectary at Malkerns ($26^\circ 34' \text{ S}$, $31^\circ 10' \text{ E}$), Swaziland, showed that daily maximum temperatures of 36°C did not noticeably lower egg production, and that the main influence of extreme weather conditions is the lethal effect on the developmental stages. van den Berg (1990) summarised reports (see Fig. 3) by van der Merwe (1923), Annecke & Chilliers (1963), Moran & Blowers (1967) and Catling (1973) on the influence of seasonal conditions and ambient temperatures under laboratory or insectary conditions on the development of *T. erytrae*.

Stage	Reference							
	Van der Merwe (1923)		Annecke and Cilliers (1963)		Moran and Blowers (1967)		Catling (1973)	
	Summer	Winter	21.8°C	18.3°C	Temperature plateau of 21°C , 4 h $^\circ\text{C day}^{-1}$ above and $38 \text{ h } ^\circ\text{C day}^{-1}$ below 20°C	Temperature of 27°C , 24 h $^\circ\text{C day}^{-1}$ above and 33 h $^\circ\text{C day}^{-1}$ below 20°C	Mean 25°C	Mean 14°C
Incubation period	5–7	?–11	8–10	11–17	9.54 (8–13)	8.06 (7–10)	6	15
Nymphal instars								
First	3–5	3–7			7.56 (4–15)	6.83 (4–11)		
Second	2–3	3–5			4.37 (2–11)	3.91 (2–8)		
Third	2–4	5–6			4.07 (3–7)	4.21 (2–8)		
Fourth	3–5	5–9			4.39 (2–7)	3.80 (3–5)		
Fifth	4–7	6–23			7.32 (5–13)	6.32 (4–9)		
Total nymphal stage	17–?	?–45	22.6°C 18–20	17.7°C up to 34	27.41 (23–35)	23.47 (21–25)	17	43
Duration of brood			Summer 25–38	Winter up to 47	36.95 (31–48)	31.53 (28–35)	Catling (1972b) June 33.8 Aug. 30.6 Sept. 30.3 Nov. 28.8 Dec. 27.8	

Figure 3. Summary of reports by van der Merwe (1923), Annecke & Chilliers (1963), Moran & Blowers (1967) and Catling (1973) on the influence of seasonal conditions and ambient temperatures under laboratory or insectary conditions on the development of *T. erytrae* (van den Berg 1990).

van den Berg et al. (1991c) observed that after hatching, the first instar nymph (crawler) of *T. erytrae* moves about to find a suitable place to **settle**. An existing dent in the plant tissue seems to be preferred. Empty galls of other nymphs are often used by one or more nymphs as settling sites. After a nymph has settled and started to feed on a leaf, an **open ‘pit’ gall** develops beneath its body. A small dent can be seen after 2 d and on the following day it becomes distinct. The gall has the same shape as the nymph's body and increases in size as the nymph grows. On the other side of the leaf a protuberance, which looks like a blister, develops. A citrus leaf with more than about 10 nymphs often curls in on the ventral side offering the nymphs additional coverage. Most nymphs

¹⁶⁰ $\text{msd} = \text{svp} \times (100 - \text{rh})/100$, where msd = maximum saturation deficit in mbars, svp = saturation vapour pressure (derived from tables) in mbars, and rh = relative humidity with temperature taken at midday and relative humidity at 15:00.

occurred on the ventral (abaxial) leaf surface¹⁶¹, with about 0.75% and 1% on the dorsal (adaxial) leaf surface and young branches. Contrary to the accepted view (van der Merwe 1923, Harris 1936, Catling 1967, Moran 1967, Moran & Blowers 1967, Catling 1978) that all nymphs are sedentary unless disturbed or crowded, van den Berg et al. (1991c) considered it likely that *T. erytreae* nymphs are only partially sedentary and that movement from the positions where they settle occur frequently.

van den Berg et al. (1991c) also observed that honeydew, excrement in the form of a white resinous paste, is voided by *T. erytreae* nymphs in the gall since the anus is on the underside of the abdomen. 'The abdomen is moved from side to side, rolling the excreta into a granule. After a few movements the abdomen is lifted slightly and, if the nymph is hanging in an upside down position, the granule falls out. If the nymph's abdomen is lower than the thorax, removing the granule seems to be easier than when the abdomen is higher. Occasionally a nymph hanging in an upside down position forms a "string" of faeces that stays attached to it. It may increase in length to more than 10 mm before it breaks off.'

Summary

The following is a brief summary of the studies on the biology and ecology of *T. erytreae*.

- the potential for populations to exist and flourish increases with increasing altitude, with populations highest in cool, moist regions up to 1280 m asl with low saturation deficits, and always low and isolated in the hot, arid lowlands (e.g., 500 m asl) with high saturation deficits;
- frequency and timing of daily saturation deficits above 3.453 kPa have major impacts on populations (Catling 1969b, Green & Catling 1971);
- main influence of extreme weather conditions is the lethal effect on the developmental stages (Catling 1969b);
- the host range in Africa includes citrus, orange jasmine, *Triphasia trifolia* and *Cl. anisata* (all introduced) and native Rutoideae, *V. lanceolata* (the favoured and possibly original host), possibly *Vepris* spp. other than *V. lanceolata*, *Z. capense* and *Toddalia asiatica* (see Appendix VII);
- host preference is influenced by season, variety, flush morphology, abundance, frequency and duration of flushing;
- psyllid populations can increase rapidly, particularly in spring when the N content of usually abundant flush growth is high and when competition between females for flush growth is low (see Catling 1971HPQ);
- *T. erytreae* populations multiply rapidly in spring and early summer and less rapidly in autumn and winter (Catling 1971);
- *T. erytreae* reproduces sexually (Catling 1973), and eggs of unmated females are infertile (Catling 1973);
- sex ratios fluctuate but females were always predominant (Catling 1973);
- mating takes place as soon as the teneral adult hardens and occurs at all times of the day (Catling 1973);
- adult longevity is 17-50 d depending on season (shorter in summer, longer in winter) (Catling 1973);
- the pre-oviposition is usually 3-5 d in summer (mean temperature 24°C-26°C) and 6-7 d in winter (14°C-16°C) (Catling 1973);
- mated females may lay 217-1305 eggs (Catling 1973: under insectary conditions);
- eggs are laid on the shoot tips of the young flush growth (van der Merwe 1923, Annecke & Cilliers 1963; Moran & Blowers 1967, van den Berg 1990);

¹⁶¹ The authors attributed this response to the fact that most stomata occur on abaxial surface and that *T. erytreae* nymphs, according to observations by Moran (1967), feed through the stomata.

- eggs hatch in 6-15 days and nymphal development takes 17-43 days, both strongly correlated with mean temperature (Catling 1973);
- there are five nymphal instars;
- the threshold temperature for nymphal development is probably between 10°C and 12°C (Catling 1973);
- nymphs form open 'pit' galls, mostly on the lower (abaxial) surfaces of immature leaves (van den Berg et al. 1991c);
- adults can disperse, with the aid of prevailing winds, at least 1.5 km (van den Berg & Deacon 1988);
- most flight activity of occurs in two peaks, the first between 10:00 and 11:00 and the second and larger peak shortly before sunset (van den Berg & Deacon 1989);
- in the absence of host plants adults live about 85 and die from desiccation rather than starvation (van den Berg & Deacon 1988);
- adults disperse more frequently as numbers of eggs, nymphs or adults on the citrus increase and when flush growth declines (van den Berg et al. 1991a); and
- movement of adults between citrus orchards and stands of alternative hosts is influenced by season (van den Berg et al. 1991b).

Version 2

Appendix XI: Management of huanglongbing and its vectors, *D. citri* and *T. erytreae*

Précis

In the absence of their vectors, *D. citri* or *T. erytreae*, the pathogens that cause HLB are most commonly spread by grafting of infected buds, marcotting (air-layering) (see da Graça 1991) and from tree to tree by root grafting (see Broadbent et al. 1988). Natural transmission by dodder (*Cuscuta* spp. [Solanales: Convolvulaceae]), as discussed in the text of the Incursion Management Plan (IMP), may occur, but has not been proven. Natural transmission in citrus seeds may occur (see Tirtawidjaja 1981) and, although recent unpublished information indicates that HLB can be transmitted through seeds to the resulting seedlings at low levels, evidence is still required to verify this, as Sagaram et al. (2008), using PCR, did not detect '*Ca. L. asiaticus*' in the endosperm and embryo of citrus seed.

Information provided by Ke and Xu (1990) suggests that effective management of HLB in the presence of *D. citri* or *T. erytreae* will require annual rates of spread (new positive detections) of the disease in orchards by either psyllid to be < 0.2% (1 in 500 trees), preferably zero. Rates of spread within nurseries and between nurseries and orchards must be zero, and rates of spread between orchards should be zero. In Australia, in the presence of *D. citri* and/or *T. erytreae*, but particularly for *D. citri*, this will only be achieved cost-effectively through area-wide use of pathogen-free rootstocks and scions, regular monitoring of trees for HLB symptoms, and mandatory elimination (as in Brazil — see: Lopes et al. 2008) of infected trees immediately after presence of the pathogen is confirmed. Under these circumstances it may be possible to continue sustainable production of citrus with integrated pest management (IPM) programs based on:

- biological control;
- minimal use of strategically timed applications of nC23 or nC24 horticultural or agricultural mineral oils¹⁶², and systemic and contact insecticides; and
- cultivation, as intercrops or groundcovers, of plants that produce volatile repellent compounds that slow ingress of *D. citri* populations, and therefore HLB, into orchards.

Australia is in the fortunate position of being able to plan and legislate for effective management programs **before** incursions of HLB and its vectors occur. Effective biological control will require importation and releases of primary parasitoids of the vectors, conditions that favour the survival and activity of these parasitoids and a range of endemic predators (particularly ladybirds, lacewings and spiders), and possible augmentative releases of predators. Greater use of windbreaks will be required and all nursery trees will need to be propagated in insect-proof screenhouses. The timing and synchronisation of flushes and levels of flushing will need to be carefully managed, where possible, by timing and frequency of irrigation, and likewise, fertiliser applications, the latter without jeopardising nutritional requirements of trees. The two primary parasitoids of *D. citri* will need to be introduced from several regions in Asia should the psyllid become established in Australia. Likewise, the primary parasitoids of *T. erytreae* will need to be introduced should it becomes established in Australia. Permits for introduction of the parasitoids should be sought before incursions of the vectors occur.

Insecticides available for suppressing psyllid populations include the organophosphates azinphos-methyl, chlorpyrifos and methidathion, the carbamate carbaryl, and the neonicotinoid imidacloprid, all of which are known from overseas reports to be effective against the psyllids. Permits for the use

¹⁶² As defined in Beattie GAC, Watson DM, Stevens ML, Rae DJ, Spooner-Hart RN (eds). 2002. Spray Oils Beyond 2000. University of Western Sydney.

of these chemicals need to be in place before an incursion of either *D. citri* or *T. erytreae* occurs. The withholding periods for these pesticides vary for their current use against a range of pests that do not include psyllids. They range from 3 days for chlorpyrifos to 14 days for azinphos-methyl and carbaryl, and 21 days for methidathion, for pesticides registered for use in sprays, to 20 weeks for imidacloprid, which is only currently registered for use as a soil drench for control of citrus leafminer (*Phyllocnistis citrella* Stainton [Lepidoptera: Gracillariidae]), black citrus aphid (*Toxoptera citricida* (Kirkaldy) [Hemiptera: Aphididae]), pink wax scale (*Ceroplastes rubens* Maskell [Hemiptera: Coccidae] and red scale (*Aonidiella aurantii* (Maskell) [Hemiptera: Diaspididae]). Current rates of each of the chemicals should be appropriate for use against *D. citri* and *T. erytreae*.

It is envisaged that use of insecticides could involve:

- a single (1) application, as a spray, of a contact-systemic insecticide (e.g., imidacloprid) in winter or early spring, before the spring growth flush commences;
- 3-4 sprays of 0.25% to 0.5% mineral oil to 'spring' growth flush, with an interval of a fortnight between sprays, and with the first spray applied when new growth on approximately 20% of trees is ≤ 5 mm long; and
- summer applications of 1-4 contact-systemic insecticides in conjunction with 3-4 0.25% to 0.5% mineral oil sprays commencing when new growth on approximately 20% of trees is ≤ 5 mm long.

It may be possible to include fungicides in some of these sprays. The aim of such programs would be to kill psyllid eggs, nymphs and adults, and to reduce feeding by adult psyllids and oviposition by adult females. **Application of sprays on the basis of psyllid numbers on new flush growth is not recommended.**

It will not be possible to prevent spread of HLB solely through chemical suppression of *D. citri* populations, and limiting rates of spread to acceptable levels through such practices will be difficult, impossible, to achieve and not economically or environmentally sustainable. Since the 1970s the 'clean and green' Australian citrus industry has been blessed by very effective biological control and IPM programs based on low pesticide use and relatively stable orchard ecosystems with low pest and disease pressures (Smith et al. 1997). *D. citri* management programs based on use of chemicals will require marked increases¹⁶³ in the annual number of pesticide applications and significant improvements in spray application (common low-profile airblast sprayers will not achieve required levels of spray coverage and air turbulence associated with their use will enhance dispersal of *D. citri* and HLB within orchards). Such programs will, through destruction of natural enemies, lead to increased use of pesticides for control of other pests, particularly scales, mealybugs, thrips and mites, which currently occur at levels rarely requiring chemical intervention. They will also:

- lead to pesticide residues that may exceed maximum residue limits (MRLs) for processing, and domestic and export¹⁶⁴ fresh fruit;
- reduce orchard biodiversity through impacts on non-target organisms (invertebrates and vertebrates);
- lead to resistance of a range of pests to pesticides; and
- increase risks and liabilities for growers and their employees¹⁶⁵.

¹⁶³ Spray applications per year could easily exceed 10 in cooler regions and 20 or more in warmer regions. In some countries in tropical Asia, sprays are applied > 35 times per year, sometimes weekly.

¹⁶⁴ http://www.australiancitrusgrowers.com/aspdev/marketing/export/mrl_listing.asp.

¹⁶⁵ Animal and Plant Health Inspection Service [Docket No. APHIS-2007-0135] Citrus Greening and Asian Citrus Psyllid; Availability of an Environmental Assessment.

In the absence of HLB it should be possible to rely on biological control, possibly in conjunction with summer-autumn mineral oils sprays and 1-2 applications of contact-systemic insecticides, for control of *D. citri*. Less chemical intervention will be required for control of *T. erythrae* than for *D. citri*.

Managing HLB

The following recommendations should be adopted to prevent occurrence and spread of HLB in post-incursion circumstances where the disease and one or both of its vectors occur in orchards in industry-recognised minor and major production areas (see Australian Citrus Industry in the IMP), and where eradication of the disease and its vectors on a national basis is not considered feasible:

- mandatory area-wide management practices within orchards and surrounding areas;
- quarterly, or more frequent, monitoring by trained personnel for symptoms of HLB in known host plants (*Citrus* and *Citrus* relatives: see Appendix IV) in orchards, nurseries, home gardens and other circumstances (e.g., parks and native vegetation) where hosts of the disease and the vectors may occur within the production area;
- confirmation of HLB infection in symptomatic leaves based on use of PCR or, alternatively, if validated as appropriate, the IST¹⁶⁶ in conjunction with light microscopy to detect phloem degeneration;
- mandatory¹⁶⁷ and immediate destruction of HLB-infected plants by cutting each trunk or stem and applying glyphosate, or an alternative herbicide, to the stump to kill the roots (this must be done without waiting to harvest any mature fruit);
- mandatory and immediate destruction of all trees in a block should the percentage of HLB-infected trees in a block reach or exceed 10% of trees within an interval of 12 months;
- mandatory destruction of abandoned orchards without the necessity to prove the presence of HLB;
- mandatory removal of HLB-infected plants in nurseries, home gardens and other circumstances (e.g., parks and native vegetation);
- mandatory removal of alternative hosts of the vectors, particularly species of *Murraya*, *Berberis* and *Clausena*, within close proximity (2 km) of orchards;
- mandatory registration of nurseries growing *Citrus* and *Citrus* relatives (particularly *Murraya* and *Berberis*);
- use of certified¹⁶⁸ or accredited pathogen-free buds produced under a certified budwood scheme (no use of uncertified buds or marcots);
- geographical isolation of budwood sources (mother trees) and their maintenance in insect-proof screenhouses;
- nursery production, in HLB affected regions, in secure insect-proof screenhouses;
- legislation to prohibit transport of HLB-infected or vector-infested plant parts (e.g., nursery trees, budwood, fruit and seeds) to unaffected areas¹⁶⁹;
- management of planting densities, canopy dimensions and canopy densities to optimise yields per hectare¹⁷⁰ and effective application of sprays;
- planting of windbreaks¹⁷¹ to minimise movement of adult psyllids within and between orchards;

¹⁶⁶ Studies are required to determine impacts of conditions other than HLB, e.g., seasons, flush maturity, winter yellows and Phytophthora on starch accumulation and the accuracy of this test.

¹⁶⁷ Legislation will be required for mandatory removal of host plants.

¹⁶⁸ A mandatory certification, or an accreditation, scheme for pathogen-free or pathogen-tested citrus budwood should be implemented as a matter of high priority in Australia.

¹⁶⁹ If a plant is infested with a psyllid it should be assumed that it may be infected.

¹⁷⁰ See: Hutton RJ, Broadbent P, Bevington KB. 2000. Viroid dwarfing for high density citrus plantings. Horticultural Reviews 24: 277-317.

¹⁷¹ The effectiveness of windbreaks will depend on several conditions including canopy density, height, spacing within and between breaks. See Owen-Turner J, Hardy S. 2006. Windbreaks for Citrus. CITGroups Australia.

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/137858/Windbreaks-for-citrus.pdf

- hedging and pruning practices¹⁷² timed and undertaken to minimise the risk of enhancing vector populations;
- orchard and nursery management of *D. citri* and/or *T. erythrae* with strategically applied insecticides and mineral oils;
 - timing of sprays should be based on host-plant phenology so as to minimise feeding and oviposition and to maximise mortality of eggs, nymphs and adults;
 - application of sprays should be even and thorough, with sprays applied to run-off;
 - use of sprayers (e.g., oscillating booms and recently available fan-assisted sprayers¹⁷³ rather than airblast sprayers) that do not assist, or at least minimise, dispersal of adult psyllids in air currents.
 - use of soil drenches and tree injections should be based on tree size and phenology, and account for potential loss or diminution of active ingredient(s) through leaching, degradation or tree growth;
- strategies to encourage, where feasible, biological control of the vectors by their natural enemies (e.g., planting of groundcover plants to encourage generalist predators);
- growing plants (as intercrops and/or ground-covers within orchards) that produce volatiles that repel the vectors, thereby slowing ingress of HLB into orchards;
- timing irrigation (where feasible) and fertiliser¹⁷⁴ applications to regulate the timing, number and extent of flush cycles; use of supplementary overhead irrigation to reduce psyllid populations; and
- education of farm and nursery personnel; pesticide manufacturers, distributors and retailers; consultants, technical advisors, and scouts; research, quarantine, regulatory and advisory staff within government departments.

Rodrigues (pers. comm. with P Barkley, 2007) outlined 16 points for farmers in Brazil to be aware of in order to manage HLB successfully:

- refusing to accept the presence of HLB;
- delaying the beginning of inspection;
- scouting by people not trained specifically for HLB detection;
- scouting the field at low frequency (e.g., once a year);
- scouting by walking in blocks with mature trees;
- skipping scouting in parts of blocks with difficult access;
- managing HLB by vector control only (without eradication);
- spraying at low frequency in younger trees (under 5 years);
- fogging insecticides for vector control (does not control the main target: nymphs);
- delaying eradication after detection of HLB symptoms (waiting to harvest fruit);
- eradicating by using fork lift (leads to root sprouts of infected tree);
- eradicating symptomatic trees only, in blocks with more than 10% symptoms;
- managing the disease by pruning of infected branches does not work¹⁷⁵;
- planting new orchard close to infected blocks;
- using nursery plants produced in open field; and
- retaining ornamental plants like *Murraya* and other specialty citrus varieties.

¹⁷² Bacon PE. 1981. The effect of hedging time on regrowth and flowering of mature Valencia orange trees. Australian Journal of Agricultural Research 32(1): 61–68.

Bevington KB. 1980. Response of Valencia orange trees in Australia to hedging and topping. Proceedings of the Florida State Horticultural Society 93: 65–66.

¹⁷³ Those developed since 2005 by Geoff Furness, South Australian Research and Development Institute, Loxton.

¹⁷⁴ The literature suggests N levels influence rates of increase of *D. citri* and *T. erythrae* populations in spring, and levels higher than those required for normal production should be avoided (see Catling 1971). Irrigation that leads to irregular flush growth should also be avoided.

¹⁷⁵ See 'Inefficacy of pruning to control citrus huanglongbing in Brazil' by Lopes et al. (2006). In contrast to experience with '*Ca. L. asiaticus*' and '*Ca. L. americanus*', pruning of infected trees with '*Ca. L. africanus*' does work for trees 6–10 years old with < 50% of the canopy infected. However, regrowth must be protected against *T. erythrae* infestations – if not, pruning is futile: see Buitendag & von Broembsen (1993).

Several key aspects of control of HLB and its two known vectors, *T. erytrae* and *D. citri*, particularly the latter, are considered in the following text: physical controls and general orchard practices; control of the psyllid vectors, including chemical control, biological control, and use of non-host plant volatiles to repel psyllids.

Physical controls and general orchard practices

Physical controls limiting the spread of HLB include removal of infected trees (Ke & Xu 1990), use of windbreaks to reduce natural dispersal of psyllids within orchards (Ke & Xu 1990), hand removal of summer flush growth (Aubert 1990b), and overhead irrigation to reduce survival of eggs and nymphs (pers. obs., GAC Beattie).

Removal of infected trees identified during annual surveys was the key component of highly successful management strategies that limited spread of HLB in large orchards in Guangdong and Fujian in the 1970s and 1980s to < 1% annually (Ke & Xu 1990). The trees were identified during annual surveys. Insecticides were also applied up to 6 times annually to suppress psyllid populations (Ke & Xu 1990): their use is reviewed below under 'Other synthetic pesticides, and insect growth regulators'. Similar practices, based on monitoring, destruction of PCR-positive trees and poisoning of their root systems, are being encouraged in Florida and Brazil (Ayres 2006, Gottwald et al. 2007). Chemical control of vectors is also required, but is ineffective unless infected trees are felled and their roots poisoned. Some growers in Florida and Brazil remove blocks of trees when the disease is detected in 10% of trees: at this point it is estimated that the disease is present in 20% of trees, twice the number of trees in which symptoms have been observed and presence of the pathogen confirmed (Irey et al. 2006).

Ke & Xu (1990) also mentioned use of horsetail beefwood (*Casuarina equisetifolia* L. [Fagales: Casuarinaceae])¹⁷⁶ windbreaks to separate every 10 ha of trees. Use of such physical barriers warrants further research to determine the most suitable plants, heights, planting distances and patterns in relation to topography, and wind directions and speeds¹⁷⁷.

Hand removal of summer flush (Aubert 1990b), to reduce the impact of citrus leafminer and *D. citri*, appears to be less common in China than it was a decade or more ago (GAC Beattie, pers. obs.). Some farmers at Sihui near Guangzhou now use 0.0008% 1-naphthaleneacetic acid (NAA) for the same purpose, but care is required as over application of the plant growth regulator can be phytotoxic (GAC Beattie, pers. comm. with farmers, 2007).

Guangdong farmers also girdle sweet orange trees twice in spring in order to increase fruit set, and sometimes in summer in order to increase the sugar content of fruit (GAC Beattie, pers. comm. with farmers at Sihui in 2007 and at Luoding in 2008). Girdling markedly increases flowering when done in autumn (Cohen 1982, Goldschmidt et al. 1985), fruit set when done at full blossom (Monselise et al. 1972, Erner 1988), and fruit size when done during fruit enlargement (Cohen 1984, Fishler et al. 1983)¹⁷⁸. In this context it is interesting to note that Martinez (1973) reported that girdling prevented movement of the '*Ca. L. asiaticus*' upwards or downwards through girdled portions of stems of mandarin and sweet orange seedlings during the term of an experiment that he undertook

¹⁷⁶ There are two subspecies of *Casuarina equisetifolia* subsp. *equisetifolia* and *Ca. equisetifolia* subsp. *incana* (Benth.) L. Johnson (Wilson & Johnson 1989). The former is typically a small tree or large shrub, 6–10 m tall, which grows exclusively in Vanuatu and along the coast of Queensland and northern New South Wales in Australia. The latter is a small to large tree (8–35 m tall) that has a wide natural distribution in subtropical and tropical coastlines from northern Queensland and the Northern Territory in Australia, throughout southern Thailand, Malaysia (Peninsular Malaysia, Sabah and Sarawak), the Philippines, Indonesia, Melanesia and Polynesia. *Ca. equisetifolia*, in particular subsp. *equisetifolia*, has been introduced into a large number of countries, and is now a common feature of the coastal landscape of most tropical and warm subtropical countries, where it is often naturalised (Pinyopusarerk et al. 2004).

¹⁷⁷ For types and impacts of windbreaks see: <http://www.lal.ufl.edu/extension/windbreaks/index.htm>, 'Living and Artificial Windbreaks for Citrus' - A Short Course, University of Florida IFAS, 2006; and, 'Windbreaks for Citrus', 2006. CITGroups Australia, 2006.

¹⁷⁸ Physiological and horticultural aspects of girdling were recently reviewed by Goren et al. (2004).

over 10 months¹⁷⁹. Girdling, as practiced by Guangdong farmers, may therefore restrict movement of '*Ca. L. asiaticus*' in infected trees and the limit the severity of infections.

The benefits of high-density plantings in the face of a HLB epidemic (Aubert 1990b) are debatable. Dense overcrowded canopies are incompatible with thorough coverage of insecticide sprays and reduce the yields on the sides of canopies. However such plantings lead to more rapid returns on investment in the first few years after planting than in less dense plantings¹⁸⁰, and by leading to higher proportions of flush growth on the top of canopies than on the sides, may lead to slower spread of the pathogen in trees—as appears to be the case in high-density plantings in the Mekong Delta of Việt Nam (GAC Beattie, pers. obs.). Reduced rates of spread may be due to phloem aging and dying naturally at rates faster than the pathogen can spread within trees.

Another potential, though problematic, approach could include temporary moisture stressing of trees to reduce survival of eggs and nymphs, but this could, if not managed correctly, damage trees and result in loss of fruit. Nevertheless, in regions such as the Mekong Delta, where trees are stressed in order to induce flowering at a time appropriate for harvesting fruit during the following Lunar New Year, such practices may contribute to lowering psyllid populations. In Japan, Satsuma mandarin orchards are water stressed prior to fruit maturing to increase sugar levels (Inoue 1989).

Movement of vehicles and equipment that may lead to spread of the HLB in an orchards (Gottwald et al. 1991) should be minimised. Airblast sprayers, and other sprayers that produce turbulent air streams, may dislodge adult psyllids from trees and carry them into air streams above orchards. Such sprayers are likely to enhance spread of HLB in orchards.

Orchards should be managed, where feasible, in a manner that enhances the effectiveness of natural enemies. Fertilisers should not be used to encourage excessive flush growth.

Control of *D. citri* and *T. erytrae*

General background. *D. citri*, with its wider distribution and capacity to thrive in a wider range of citrus producing regions than *T. erytrae*, is the more difficult to manage of the two known insect vectors of HLB. However, in the absence of HLB, orchard populations of both vectors can be maintained below economic thresholds by natural enemies (two primary parasitoids, coccinellid beetles, lacewings, spiders and entomopathogens), heavy rainfall and overhead irrigation that can dislodge eggs and nymphs from flushes, and by a range of chemicals applied to trees as sprays, soil drenches or trunk applications.

Populations of *D. citri* under natural conditions in its native southern Asia were most probably restricted in size and distribution by low saturation deficits, low rainfall, natural enemies, and scarce seasonal host-plant flush growth suitable for oviposition and development of nymphs. Host-preference reports for *B. koenigii* (Aubert 1987a,b, 1990a, Lim et al. 1990a,b) and observations of infestations on '*M. paniculata*' and '*M. exotica*' in current field experiments in Indonesia (Siti Subandiyah, Universitas Gadjah Mada, pers. comm.) suggest that the suitability of plants as hosts of the psyllid may also be influenced by variable phytochemistry of single host species and hybrids (as is evident in variable pungency of leaf volatiles from forms of kaffir lime and curry leaf). It seems likely that the original hosts, possibly *B. koenigii* or *M. paniculata* (ss), occurred within tropical and

¹⁷⁹ The results of a girdling experiment reported by Martinez (1973) suggest that spread of infection in trees may also be related to rates of movement of bacteria in phloem in relation to rates of formation and natural death of phloem bands. Each flush cycle leads to a new band of phloem being formed by cambium in limbs and trunks of trees, and incorporation of the naturally dying outer band of phloem into the outer bark of trees. Pathogens in such phloem would also die. It is highly likely that the structure of phloem bands, with zones of functioning and non-functioning sieve elements, would limit movement of HLB pathogens from one band to another. Thus, movement of the pathogens in most instances would be vertical and spread of bacteria over short distances within canopies of small trees, with abundant young flush, would be more rapid than over greater distances in mature trees with proportionally fewer young flushes.

¹⁸⁰ Hutton RJ, Broadbent P, Bevington KB. 2000. Viroid dwarfing for high density citrus plantings. Horticultural Reviews 24: 277-317.

subtropical forests, in poor light under dense canopies of other trees, or on the fringes of such forests. Aubert (1988a) states: 'Unlike *Trioza erythrae*, the Asian citrus psyllid is not able to build up massively on a wide range of alternate rutaceous forest trees or shrubs'.

The psyllid's high fecundity, its ability to flourish on non-water stressed plants in hot climates (in which summer temperatures frequently exceed 40°C) with high saturation deficits, and the ability of females to detect very young flush growth, reflect its adaptation to such environments. Its pest status in modern citriculture is due to these adaptations, which allow its populations to increase very rapidly in orchard monocultures where young flush growth is seasonally abundant and encouraged through the use of irrigation and fertilisers. Aubert (1988a) considered *D. citri* to be an opportunist in its natural environment.

In contrast to *D. citri*, populations of *T. erythrae*, under natural conditions in its native sub-Saharan Africa, are restricted by high saturation deficits, natural enemies, and seasonal flush growth, suitable for oviposition and development of nymphs, on its hosts, particularly *V. lanceolata* (Moran 1968). Because *T. erythrae* is adapted to relatively cool, higher altitude, low-saturation deficit environments (Catling 1969b, Green & Catling 1971, Samways 1987) it is, and will remain, a less important vector of HLB than *D. citri*, which is adapted to lower altitude, warm to hot, high saturation environments (see Appendix IX).

Control of the psyllids has rarely been expressed in terms of the impact of insecticides and other chemicals on spread of the disease. Disproportionately less emphasis has been placed on control of HLB and its vectors than on detection methods and the production of pathogen-free trees. Disproportionate emphasis has also been placed on killing psyllid nymphs and adults. This narrow focus has led to limited studies on the use of repellents to alter the behaviour of the psyllid, particularly feeding and oviposition behaviour.

Chemical control. Chemicals used to suppress *D. citri* and *T. erythrae* populations fall into three major groups; (a) plant extracts, primarily used to kill (poison) or alter the behaviour of nymphs and adults; (b) mineral oils used to kill (physically) eggs, nymphs and adults, and/or to alter the behaviour of nymphs and adults; (c) contact and systemic synthetic pesticides primarily used to kill (poison) nymphs and adults.

There is no instance in which use of chemicals has prevented spread of the Asiatic form of HLB when transmitted by *D. citri*. In many instances where control has been reported as significant, or very effective, the impacts on spread of the disease are most probably minimal given the size of populations when treated and levels of generally short-term suppression achieved. There are situations where natural control appears to have been more effective in the long-term than chemical control (Qureshi & Stansly 2007), but not to a level that would prevent spread of the disease. It is axiomatic that natural enemies require hosts, and that the presence of psyllids in an orchard will lead to spread of the disease, if it is present.

There appear to be no records of relationships between dose of insecticide applied (e.g., for sprays, deposits cm⁻² in relation to concentration of active ingredient and spray volume ha⁻¹) and level of control achieved. Most literature on the efficacy of sprays has focused on generally meaningless concentrations of active ingredient or quantities of active ingredient per acre or hectare, particularly in the United States of America, without regard to spray volumes, the effectiveness of sprayers, and quantities of chemicals applied to sprayed surfaces. Formulations and concentrations of active ingredients evaluated in sprays have varied and spray volumes are not generally reported. Literature on the efficacy of systemic insecticides applied as soil drenches in relation to soil type, rainfall, irrigation practice, and their movement in plants in relation to their water solubility and tree type, height and age is limited. Likewise, only limited information is available on the efficacy of systemic

insecticides applied to trunks (injected or painted), as soil drenches in relation to soil type, rainfall, irrigation practice, and their movement in plants in relation to their water solubility and tree type, height and age. Comparison of efficacy reports is therefore difficult, and effective use of soil and trunk applications of systemic pesticides may be limited to young trees, 1-2 years after planting.

The fact that infective *D. citri* adults can transmit the HLB pathogen shortly after feeding on a plant (Capoor et al. 1974) and that they may transmit the disease as they acquire fatal doses of systemic pesticides, particularly when the chemicals are applied as trunk and soil applications, seems to have been largely ignored. Estimating dose accurately requires knowledge of likely influences of environmental conditions, soil characteristics, and tree size, growth rates and phenology.

Laws governing the use of pesticides, environmental and health concerns¹⁸¹ and associated maximum residue levels (MRLs) and withholding periods, restrict the choice of chemicals, doses, and timing and frequencies of applications. Choice of chemicals is generally restricted during harvest, and in the weeks immediately before harvest. Application costs (products, labour and equipment) may also be prohibitive: spread and severity of the disease in Asia has been linked to farmers not applying insecticides when market prices for fruit fall below the cost of production. Furthermore, frequent use of synthetic pesticides is unlikely to be sustainable for several reasons. These include: (a) development of resistance in the psyllid and in aphids, scales, mealybugs, thrips and citrus leafminer; (b) induced outbreaks of major secondary pests following disruption of biological and IPM programs; (c) reduced fruit quality caused directly by pesticides, and solvents used in their formulation, and indirectly as a result of outbreaks of secondary pests; and (d) potential residues in mature fruit.

Chemicals were first used for control of *D. citri* in the early 1900s. The initial recommendations appear to have been made by Fletcher¹⁸² (1917, 1919) who recommended use of fish oil soap and fish oil-resin soap as contact sprays, for control of the psyllid. Husain & Nath (1927) recommended use of crude oil, tobacco decoction or resin compound in sprays applied at about 4.6 L of spray per tree¹⁸³. Pruthi & Mani (1945) made similar recommendations.

Since 1950, many chemicals have been evaluated and/or used in management programs as sprays for the control of *D. citri*. These include:

- organochlorines, carbamates, organophosphates (e.g., Ahmad 1961¹⁸⁴, Buitendag 1972, 1976, Hughes & van Dyk 1972, Bindra et al. 1973, Schwarz et al. 1974, Milne 1977, Milne & de Villiers 1977, Puri & Singh 1977, Pyle 1977, Wortmann & Schafer 1977, Nariani 1981, Buitendag & Bronkhorst 1986, Buitendag & Bronkhurst (sic) 1983, Bhagabati & Nariani 1983, Khangura & Singh 1984, 1985, 1986, Nurhadi 1986, Batra et al. 1990, Ke & Xu 1990, Xu et al. 1991, Rathgeber 1992, Dahiya et al. 1994, Xu et al. 1994, Singh et al. 1995, Chakravarthy et al. 1998, Chen 1998, Patel et al. 1998, Peña et al. 1999, Dadmal et al. 2002, Leong et al. 2002, Ahmed et al. 2004, McKenzie et al. 2004, Childers & Rogers 2005, Leong 2006, Deng & Shi 2006, 2007, Qureshi & Stansly 2007, 2008);
- pyrethroids, thioureas, neonicotinoids (e.g., Chakravarthy et al. 1998, Patel et al. 1998, Childers & Rogers 2005, Nakano et al. 1999, Ahmed et al. 2004, McKenzie et al. 2004, Leong et al. 2002, Deng & Shi 2006, 2007, Gatineau et al. 2006, Leong 2006, Quach et al. 2008, Srinivasan et al. 2008);

¹⁸¹ Animal and Plant Health Inspection Service [Docket No. APHIS–2007–0135] Citrus Greening and Asian Citrus Psyllid; Availability of an Environmental Assessment

¹⁸² T (Thomas) Bainbridge Fletcher (1878-1950) was the second Imperial Entomologist appointed in India. He was based at the Imperial Agricultural Research Institute, Pusa, Bihar (http://www.thebestlinks.com/T._Bainbridge_Fletcher.html). He appears to have been the first to make written recommendations (in English) for use of chemicals to control of *D. citri*.

¹⁸³ This is similar to some current recommendations for use of mineral oils and the neonicotinoid imidacloprid.

¹⁸⁴ In one trial with azinphos-methyl, this author estimated that there were > 4.5 million psyllids on 110 trees (0.4 ha) before spraying commenced. If such populations occurred in orchards and if 99% mortality were achieved there would still be > 45,000 live psyllids/ha, > 400 per tree. One infected psyllid can transmit HLB to a healthy plant.

- plant oils and other plant extracts from a range of plants, including, *Annona squamosa* L. [Magnoliales: Annonaceae], *Azadirachta indica* A. Juss. and *Melia azedarach* L. [Sapindales: Meliaceae], *Madhuca longifolia* (J.König ex L.) J.F.Macbr. [Sapotales: Sapotaceae], and *Pongamia pinnata* (L.) Pierre [Fabales: Fabaceae] (e.g., Wu & Faan 1988, Chakravarthy et al. 1998, Dadmal et al. 2002, Rao et al. 2008);
- mineral oils (e.g., Rae et al. 1997, Leong et al. 2002, Leong 2006);
- particle films (e.g., McKenzie 2002, Hall et al. 2007); and
- alkylsilicone wetters (e.g., Srinivasan et al. 2008).

All of the products tested were more effective than not spraying. Application of some products led to high levels of psyllid mortality, with synthetic pesticides giving higher levels of mortality than most plant oils and plant extracts. Direct comparisons are difficult, as chemicals evaluated, formulations, methods and frequencies of application, quantities applied, and orchard and other conditions have varied markedly. Furthermore, only studies reported by Ke & Xu (1990) on the use of synthetic pesticides, Leong et al. (2002) and Leong (2006) on the use of synthetic pesticides and mineral oils, and Gatineau et al. (2006) on the use of fenobucarb and imidacloprid, and were undertaken over durations of one to two years, or longer (see detailed summaries below).

Until relatively recently, Ke & Xu (1990), Xu et al. (1991), Gatineau et al. (2006) and Leong (2006) appear to be the only authors to have reported impacts of chemical controls of *D. citri* on the spread and incidence of HLB. Ke & Xu (1990) appear to be the only authors to have reported long-term (> 10 years) use of insecticides in programs based on rigorous detection and destruction of HLB-infected trees within orchards. Xu et al. (1991) and Leong (2006) reported impacts over 4 years, and Gatineau et al. (2006) impacts over 2 years.

More recently, Bergamin-Filho et al. (2008) related the number of insecticide sprays with HLB incidence, in a commercial orchard in Brazil. A total of 716,476 orange trees, from 5 to 10 years old, distributed in 357 blocks were submitted to a different number of insecticide sprays (3 to 12) during three growing seasons (2004/2005, 2005/2006, and 2006/2007). Eradication of symptomatic trees was carried out in the whole area 4 to 8 times per growing season. Incidences of HLB in all blocks ranged from 0% to 8.35 % of symptomatic trees. There was no negative relationship between the number of sprays and HLB incidence (eradicated plants), considering each one of the three growing seasons. No relationship was also observed between the average number or the total number of insecticide sprays per block and the eradicated plants in the last season (to minimise the influence of a long latent period). These results suggest that, the low incidence of HLB was mainly due to eradication of symptomatic trees rather than to insecticide sprays. The grouped blocks with the highest rates of disease progress were close to another farm, which had no management of the disease and served as source of inoculum. Insecticide sprays did not prevent HLB-bacteria transmission by infectious psyllids from this external source. The grouped blocks with the lowest final incidences were located in the centre of the farm.

The following text focuses on:

- imidacloprid;
- other synthetic pesticides, and insect growth regulators;
- neem and other botanical derivatives;
- mineral oils;
- particle films;
- spray application; and
- timing and frequency of chemical treatments.

Imidacloprid. Gatineau et al. (2006) compared three treatments under *D. citri* and high HLB pressure in three 0.5 ha unreplicated King orange (*C. × aurantium*) orchards in the Mekong Delta in

Việt Nam over 2 consecutive years: untreated, fenobucarb applied fortnightly (every two weeks), and imidacloprid applied monthly. All trees were pathogen free when planted. At the end of the experiment, PCR-tests confirmed infection levels of HLB in the initially pathogen trees were approximately 96%, 75% and 24% respectively. High numbers of adults and nymphs psyllids were observed in the control. Numbers in the two insecticide treatments were more than 90% lower than in the unsprayed control. Very few adults were observed in the imidacloprid treatment and no nymphs reached the final instar in this treatment. The results demonstrated that significant transmission of HLB can occur even when high levels of control of the vector are achieved. For imidacloprid, it is clear that transmission occurred before lethal quantities of imidacloprid were ingested by some adult psyllids that entered the treatment area from neighbouring orchards. For fenobucarb, it is clear that fortnightly sprays of this contact insecticide were less effective than monthly trunk applications of imidacloprid: weekly applications may have given better control, but HLB levels after two years would probably have still been higher than in the imidacloprid treatment. Clearly, better results may have been achieved in larger orchards and in regions with lower pest and disease pressure. However, the results show that pesticides may slow ingress of HLB into orchards, but they may not prevent it, particularly in regions where high populations of *D. citri* can occur.

In studies undertaken at the Plant Protection Research Institute in Hà Nội, Việt Nam, as part of research funded by the Australian Centre for International Agricultural Research, the impact of imidacloprid on the longevity of psyllid adults after application of the pesticide as a soil drench, (three treatments involving application of 50 mL of 0.2%, 0.4% or 0.6% w/v solutions per potted two-year old tree), the results showed that levels of adult psyllid mortality fell as the number of weeks after application of the chemical treatments increased. Some 9-20% of adults were still alive 24 hours after feeding on plants treated two weeks earlier and 17-32% of adults were still alive 24 hours after feeding on plants treated 10 weeks earlier (Quach et al. 2008).

Other studies on *D. citri* involving imidacloprid include those reported by Chakravarthy et al. (1998), Nakano et al. (1999) and Ahmed (2004). Chakravarthy et al. (1998) reported that sprays of 0.025% profenphos, 0.025% trizophos and 0.025% imidacloprid gave complete control of *D. citri* on 10 year-old sweet orange trees after 7 days in a trial comparing the three synthetic pesticides with products derived from plant and animal sources. Nakano et al. (1999) found applications of two formulations of imidacloprid to be as effective against *D. citri* as trunk applications of 5 mL Confidor 100 AL per plant to be as effective as 10 mL per plant, and 2.5 mL Winner 200 SL at per plant to be as effective as 5 mL per plant. Assessments were undertaken at 3, 7, 14, 21, 28, 45 and 60 days after application. Ahmed et al. (2004) reported that foliar sprays of 500 mL methamidophos, 300 mL dimethoate and 250 g imidacloprid per acre had almost equal effects on populations of *D. citri* on mandarin and orange trees in Pakistan, over one week after application.

Srinivasan et al. (2008) recorded mixed results when alkylsilicone wetters were used as adjuvants at 0.05% for imidacloprid against *D. citri* eggs, nymphs and adults in laboratory and field studies. In an initial field test, applications of water and one of the wetters (Silwet L-77) had similar impacts on psyllid nymphs over 5 weeks, with numbers of nymphs declining rapidly and significantly immediately after sprays were applied. In a laboratory test, an LD₉₉ of 0.0045% was derived for Silwet L-77 and in a second field trial the wetter caused significant adult mortality. The wetter improved the effectiveness of imidacloprid against adults but not eggs, in shoot-dip bioassays. In another field trial, it was as effective against nymphs as 0.0135% imidacloprid alone, or with 0.00135% imidacloprid. However, with caged adults 0.0135% imidacloprid was the only one of these treatments that was effective against adults, and it only differed significantly from the other treatments for the first 2 weeks. In further laboratory tests, 0.05% Silwet L-77 and another alkylsilicone, Kinetic at 0.5%, caused significant nymphal mortality, but neither had an impact on

eggs, nor on the effectiveness of imidacloprid against either eggs or nymphs. Other assessments showed that the residual toxicity of imidacloprid was enhanced by both wetters.

Imidacloprid is a systemic broad-spectrum insecticide and acts as a contact and stomach poison against sucking and some biting insects (Sur & Stork 2003). Spray applications lead to only partial uptake of the insecticide. For example, application of imidacloprid 25 WP to apple (*Malus pumila* Mill. [Rosales: Rosaceae]) fruit led to 28% of applied active ingredient being recovered after 14 days. Of this, 65% was recovered from the fruit surface (Sur & Stork 2003). The active ingredient is translocated acropetally in xylem to shoots and leaves and accumulates preferentially in leaf parenchyma (Mendel et al. 2000, Sur & Stork 2003); it has negligible phloem mobility and therefore, it has poor basipetal translocation to sinks, i.e. storage organs, roots and fruits (Sur & Stork 2003). Consequently, highest residues are expected to occur in the older leaf parts (Sur & Stork 2003). For soil applications, root uptake and translocation into the xylem is a prerequisite for entering the phloem and in turn to be taken up by sucking insects (Sur & Stork 2003). Quick degradation after soil application has been observed, and rates of degradation after spray applications tend to be lower than for soil applications (Sur & Stork 2003).

Uptake and movement of imidacloprid in citrus has been reported by Mendel et al. (2000) and Castle et al. (2005). Mendel et al. (2000) reported that 54% of imidacloprid applied to the trunks of 2-year-old potted sweet orange trees was detected within plants 30 days after application; with 16.5% and 5.8% respectively being found in upper young and old leaves and > 29% in the bark within area of application. In other studies, Castle et al. (2005) found that uptake of imidacloprid in mature orange and lemon trees (all > 7 m high) following application in irrigation systems in an orchard at Riverside in California peaked 6-8 weeks after application and were sustained for another 6-10 weeks. Within-tree distributions (upper and lower canopy, and quadrant) did not differ significantly (Castle et al. 2005).

Activity of trunk and/or soil applications of imidacloprid against citrus pests has been reported by Castle et al. (2005) and Curkovic & Cataldo (2005). Curkovic & Cataldo (2005) compared foliar and trunk applications of imidacloprid with foliar applications of chlorpyrifos for control of long-tailed mealybug (*Pseudococcus longispinus* [Hemiptera: Pseudococcidae]) on fruit on 5 year-old orange trees in Chile. The trunk applications of imidacloprid were not as effective as the foliar applications: this was attributed to reduced absorption and/or translocation of imidacloprid to the fruits. Castle et al. (2005) assessed the efficacy of the pesticide applied through an irrigation system for control of glassy-winged sharpshooter (*Homalodisca coagulata* (Say) [Hemiptera: Sternorrhyncha: Cicadellidae]) on mature orange and lemon trees (all > 7 m-high) in 2001 and 2002. Substantial reductions in nymphs and adults were observed in imidacloprid-treated trees during the 2001 and were sustained for 4–5 months after treatment. Treatment effects on nymphs were not as well pronounced in the 2002 trial, when overall infestations were much reduced from the previous year. However, consistently lower adult infestations were still observed in 2002 for both treatments compared with untreated trees (Castle et al. 2005). The authors (Castle et al. 2005) attributed survival of some nymphs and adults for considerable periods to possible antifeedant effects of imidacloprid based on studies on the aphids *Myzus persicae* (Sulzer) and *Myzus nicotianae* Blackman [Hemiptera: Sternorrhyncha: Aphididae] (Nauen et al. 1998a) and the whitefly *Bemisia tabaci* (Gennadius) [Hemiptera: Sternorrhyncha: Aleyrodidae] (Nauen et al. 1998b). However, it is doubtful that the level control of *H. coagulata* adults that was achieved would have been sufficient to prevent transmission of *Xylella fastidiosa* (Wells, Raju, Hung, Weisburg, Parl & Beemer) (γ -Proteobacteria), the cause of Pierce's disease in grapes (*Vitis vinifera* L. [Vitales: Vitaceae]) and citrus variegated chlorosis¹⁸⁵. Furthermore, if such antifeedant effects occur for *D. citri*, they may

¹⁸⁵ Hartung et al. 1994. Citrus variegated chlorosis bacterium: axenic culture, pathogenicity, and serological relationships with other strains of *Xylella fastidiosa*. *Phytopathology* 84: 591-597.

not have contributed significantly to reduced transmission of HLB in the study reported by Gattineau et al. (2006).

In studies related to those reported by Curkovic & Cataldo (2005) on citrus, Sazo et al. (2006) assessed the efficacy of two imidacloprid formulations as foliar sprays and as treatments applied to the trunks of five year-old avocado (*Persea americana* Mill. var. *americana* [Laurales: Lauraceae]) trees with pistol sprayers or paint brushes for control of *P. longispinus* on leaves. They found that foliar application was more effective than the trunk applications. This was attributed to reduced absorption and translocation of imidacloprid after trunk application. Tattar et al. (1998) studied the efficacy of trunk and soil-injected applications of imidacloprid in Canadian hemlock (*Tsuga canadensis* (L.) Carrière [Pinales: Pinaceae]), white pine (*Pinus strobus* L. [Pinales: Pinaceae]) and pin oak (*Quercus palustris* Münchh. [Fagales: Fagaceae]) trees with trunk diameters of 25 to 45 cm at breast height. Soil applications required 8-12 weeks for imidacloprid to reach lethal concentrations (≥ 15 ppm) to sucking pests in each of tree species. Stem-injections were more variable, taking 1 and 4 weeks respectively for *Q. palustris* and *T. canadensis*, but 5 months for *P. strobus*.

Under standard laboratory conditions, imidacloprid has a half-life of 156 days under aerobic degradation. Sunlight and anaerobic conditions accelerate degradation. The insecticide does not accumulate in soil. The degree of binding of imidacloprid to the soil is high and is not readily released. Thus the overall effect is that the compound remains in the upper root zone. It is not stable in an aqueous environment (Krohn & Hellpointner 2002).

Other synthetic pesticides, and insect growth regulators. Studies on the use of insect growth regulators and contact and systemic synthetic insecticides other than imidacloprid against *D. citri* and *T. erytrae* are summarised here. However, this section may contain information about imidacloprid that was not mentioned above or elsewhere in this appendix. Some papers include information about mineral oils and other chemicals that may be repeated elsewhere.

Hughes & Dyk (1972) compared the impact of aerial applications of monocrotophos on *T. erytrae* populations in five citrus orchards. The percentage of new growth infested by nymphs 3 days after treatment with 0.6% in 94 L of spray/ha and 0.6%, 1.2% and 1.8% in 47 L of spray/ha was 5, 15, 18, and 17% respectively, compared to 98% in the unsprayed control. After 13 days, the percentages were 11, 21, 16 and 23% respectively compared to 93% in the control. The percentage of new growth on which eggs hatched and nymphs settled averaged 14, 18, 32 and 40% as compared with 98%. These results indicate that the higher spray volume was more effective than the lower volume, and that increasing the concentration of active ingredient at the lower volume did not result in increased efficacy.

Bindra et al. (1973) reported that 0.05% sprays of monocrotophos, dimethoate, fenthion, fenitrothion, methyl demeton, endosulfan, phosphamidon, diazinon and formothion, and 0.05% malathion plus 0.1% DDT proved promising against *D. citri*, in declining order of efficacy, in a preliminary experiment for control of nymphs when applied as sprays at 600 L/ha to 4.6 m-high sweet orange trees. In a second experiment, sprays of 0.05% dimethoate, monocrotophos, endosulfan, fenitrothion, fenthion and diazinon were promising in their order of effectiveness against nymphs and adults. Dimethoate was regarded as preferable, owing to its relatively low cost, and low dermal toxicity to humans.

Puri & Singh (1977) compared the effectiveness of foliar applications of monocrotophos for control of *D. citri* nymphs with applications to trunks (2.5 and 5 cm wide bands) and applications to soil (single spots, 4 spots and ringed). Foliar applications of 0.2, 0.4, 0.6 g a.i./plant were the more persistent over 28 days than the other forms of applications at the same rates. The general order of

increasing persistence was a single spot to soil, ring application to soil, four spots to soil, 2.5 cm band to trunk, 5 cm band to trunk and foliar spray.

Buitendag & Bronkhurst (sic) (1983) applied aldicarb granules in bands to the trunks of citrus trees for control of *T. erythrae*. Good control was achieved on young trees, but effectiveness decreased progressively as the trunk diameter increased above 125 mm.

Buitendag & Bronkhorst (1986) reported that trunk applications of monocrotophos controlled *T. erythrae*: Fig. 1 shows the relationship between trunk diameter and g a.i. of monocrotophos that they applied for complete control of the psyllid over a period of 30 days.

Nurhadi (1986) compared foliar sprays of 0.2% monocrotophos and 0.2% dimethoate, and soil applications of 69 g aldicarb per tree for control of *D. citri* over 3-4 months in Java. The sprays gave the best control. He commented that aldicarb was less effective than the sprays in controlling the population growth of *D. citri*, but better than the untreated control. He did not comment on why aldicarb was not effective.

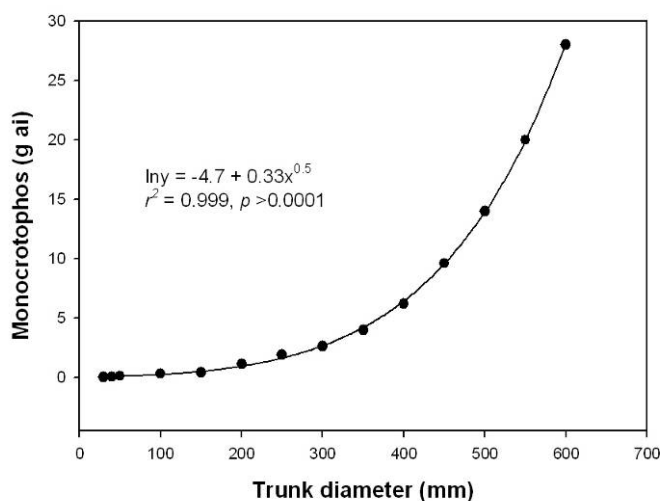


Figure 1. Relationship between trunk diameter and g a.i. of monocrotophos required for complete control of *T. erythrae* over a period of 30 days. Buitendag & Bronkhorst (1986): this relationship was also used in a study reported by Rathgeber (1992) on use of monocrotophos to control *D. citri*.

Ke & Xu (1990) reported successful control of HLB and *D. citri* based on planting of pathogen-free trees, eradication of alternative hosts (*Cl. lansium* and *M. paniculata*), early eradication of diseased trees, use of windbreaks, careful implementation of irrigation, fertiliser and pruning practices, and targeted insecticide sprays in several orchards in the coastal region of subtropical southern China, where winters are cool to cold. On one large (909-1467 ha bearing trees) collective farm at Yangcun in eastern Guangdong, 1-2 insecticide sprays were applied before spring budbreak. These sprays (mostly ca. 0.1% dimethoate or 0.1% parathion) were followed by single applications during the spring, summer and autumn flushes. Rates of infection on this farm fell from about 7% in 1978 to < 1% over 12 years, and averaged 2%. At another, smaller farm (54-81 ha bearing trees) near Fuzhou, in Fujian, levels fell from 2.8% over 11 years from 1979 to < 1%, and averaged 1%. Xu et al. (1991) reported successful outcomes of similar management strategies to reduce numbers of infected trees over 4 years in two orchards near Fuzhou. In both instances trees were inspected and diseased trees eradicated. Insecticides were applied as sprays, on average 12 times annually, and no psyllids were recorded. These farms, particularly large ones such as Yangcun, were centrally managed, with a network of technicians overseeing control of the disease and the vector. This system of management ceased in the 1990s when individual farmers assumed responsibility for

small areas (generally < 0.5 ha). When this occurred, levels of HLB increased rapidly, as central supervision declined and market forces and alternative employment opportunities led to declining and variable inputs into production: see Zhou et al. (2008) for additional information.

In the second¹⁸⁶ major review of huanglongbing, da Graça (1991) considered systemic insecticides to be the most effective pesticides against both *D. citri* and *T. erytraeae*. For *T. erytraeae*, he mentioned use of endosulfan (a contact pesticide) on the Mazoe Citrus Estates in South Africa (Pyle 1977), use of monocrotophos sprays (Buitendag 1972), aerial application of sprays (Hughes & van Dyk 1972), trunk applications (Buitendag & Bronkhorst 1986), trunk injections (Schwarz et al. 1974), and soil applications of dimethoate (Milne 1977, Milne & de Villiers 1977, Wortmann & Schafer 1977). He noted that weekly sprays of monocrotophos did not prevent HLB (Buitendag 1976), that single applications of dimethoate by microject and drip irrigation gave control for over 7 weeks, and the two applications gave season-long protection (Milne & de Villiers 1977). The following pesticides were registered for use in foliar sprays for control of *T. erytraeae* in 1998: chlorpyrifos, dimethoate, endosulfan, isofenphos, mevinphos, monocrotophos, oxydemeton methyl and profenphos. Monocrotophos and methamidophos were registered for trunk treatments, and dimethoate for soil treatments (Bedford et al. 1998).

Rathgeber (1992) compared the effectiveness of bark applications of monocrotophos, soil applications of dimethoate, and foliar sprays of endosulfan for control of *D. citri* on 3-4 year-old mandarin trees at Turen in East Java. Dose of monocrotophos (15% EC) per tree, and the height above ground level at which the chemical was applied, were based on trunk circumference at the narrowest point on each tree, in accordance with procedures developed by Buitendag & Bronkhorst (1986) for control of citrus pests in South Africa. Doses ranged from 0.04 mL ai for trunks 30 mm in diameter to 12 mL ai for 450 mm trunks: applications to trunks with diameters > 20 mm required application all around the trunks. Dimethoate (40% EC) was applied at 4 mL ai per m² of tree shade area (an average of 12 mL was required per tree). Endosulfan (35% EC) was applied as a light cover spray at 0.525 mL ai per tree. Soil application of dimethoate was the least effective and most expensive treatment. Endosulfan and monocrotophos gave good results when applied on 4 occasions at 3-week intervals. In contrast to dimethoate and monocrotophos, endosulfan was effective against eggs and it had the shortest harvest interval. It gave rapid control of high and medium populations but even application of sprays was essential. The cheapest treatment was monocrotophos.

Singh et al. (1995) found dimethoate and monocrotophos to be more effective than five other insecticides (thiodemeton, phorate, formothion, morphothion and phosphamidon) against *D. citri* when the pesticides were applied at concentrations ranging from 0.01% to 0.05% in foliar sprays.

Chakravarthy et al. (1998) compared nine chemicals (6 from plant or animal extracts) for control of *D. citri* on 10-year-old sweet orange trees in Andhra Pradesh in 1997. The authors reported that profenofos (0.025%), triazophos (0.025%) and imidacloprid (0.025%) produced complete control 7 days after spraying and mentioned that 0.0003% azadirachtin and 1% neem (*Azadirachta indica* A. Juss [Sapindales: Meliaceae]) oil also achieved high levels of control (> 96%) after 7 days.

Chen (1998) noted that, for control of *D. citri* and black citrus aphid, dimethoate, malathion and carbofuran needed to be applied when flushes occur. No mention was of application frequency or whether these chemicals were applied separately or in 'cocktails'. Chen (1998), citing Lin et al. (1973) and Huang et al. (1990), also mentioned that monocrotophos brushed onto bark at the base of branches at the onset of the spring flush gave effective control of *D. citri* and application of methomyl or malathion sprays at 10 day intervals is at 10-day during spring.

¹⁸⁶ The first was published by Otake (1990).

Peña et al. (1999) compared 0.075% chlorpyrifos, and 0.015% and 0.02% pyridaben (an acaricide), in single hand-gun applications at 760 L of spray/ha to *D. citri*-infested 6-year-old lime trees in Florida. Psyllid egg densities over 14 days were similar and significantly lower on sprayed trees than on unsprayed trees. Numbers of nymphs did not differ significantly between treatments over 7 days but were significantly lower in the chlorpyrifos treatment than in the other treatments after 14 days. Numbers of adults were significantly lower in all sprayed treatments 7 days after treatment but differences 1, 3 and 14 days after treatment were not significant. The authors recommended that the products be evaluated in combination with adjuvants such as mineral oils and alkylsilicones.

A review by Shivankar et al. (2000) of studies on *D. citri* led the authors to recommend two to three sprays of monocrotophos, dimethoate, thiodementon at 10-15 day intervals, soil application of aldicarb or dimethoate or trunk treatment with monocrotophos for control of the psyllid.

McKenzie et al. (2004) compared an untreated control with foliar applications of 13.3% v/v nC23 HMO, 0.13% fenpropathrin, and two non-ionic surfactants, Agri-50 SC and SA-2002 at 0.5% and 1.35% respectively, and a soil application of imidacloprid (100 mL ai/tree) for control of *D. citri* on 1 m-tall, 2-year-old sweet orange trees during the rainy season in Florida. The sprays were applied twice, 10 days apart on 16 and 26 May (late spring), at 140 L/ha using a Curtec® Prop ultra-low volume sprayer equipped with 4 cross-flow fans and rotary atomisers (2 per tree). The imidacloprid treatment was applied on 16 May. Depending on the lifecycle stage evaluated, mean mortality in the oil (73% to 91%) and fenpropathrin (85% to 95%) treatments did not differ significantly over 35 days, and the levels of control were considered excellent. The non-ionic surfactants, SA 2002 (0.0025% 2-butoxyethanol) and Agri-50 (28% propylene glycol alginate) significantly reduced numbers of psyllids compared to the untreated control. Imidacloprid performed as well (43-65% mean mortality) as the surfactants. No phytotoxicity was observed. The sprays treatments were applied when adults, nymphs and eggs were present immature flush.

Childers & Rogers (2005) used a 'pul-Tank' sprayer at 2,338 L/ha and an airblast sprayer at 3,273 L/ha to apply sprays for control of *D. citri* on 1.2 to 1.5 m-high sweet orange trees. The sprays appear to have been applied when young flush growth was 2 cm, or more, in length, as pre-treatment numbers of adults per flush were 6.3 in the first instance and 2.2 in the second. Eggs and nymphs appear to have been present in both instances. The performances of the sprayers were not compared. In the first instance, the treatments were 0.00025% abamectin and 2.8% nC23 HMO, 0.006% fenpropathrin, 0.002%, 0.002% spinosad, 0.045% chlorpyrifos, 0.002% imidacloprid and 0.002% acetamiprid. The most three most effective treatments 4 days after the application of sprays were abamectin with oil, fenpropathrin and imidacloprid. In the second instance, the treatments were 0.001% thiamethoxam, 0.0002% abamectin and 1.4% nC23 HMO, 0.0045% fenpropathrin, 0.001% spinosad, 0.033% chlorpyrifos, 0.0008% imidacloprid and 0.0015% acetamiprid. The four most effective treatments were thiamethoxam, abamectin with oil, chlorpyrifos and imidacloprid. Results in both trials were quite variable, and none of the treatments, with the possible exception of thiamethoxam, reduced numbers of psyllid adults, eggs and nymphs to zero over intervals of 19 and 25 days post-treatment. The timing of these sprays is discussed below in the section on mineral oils.

Deng & Shi (2006, 2007) evaluated a range of pesticides for control of *D. citri* in citrus orchards in Guangxi, China. In the first study (Deng & Shi 2006), mortality 24 h after sprays were applied was: < 80% for dichlorvos, dimethoate, phoxim, malathion, acephate, abamectin and diafenthiuron; 86.6% for imidacloprid; and > 90 % for fenpropathrin alone, fenpropathrin + triazophos, fenpropathrin + profenofos, fenpropathrin + isocarbophos, beta-cypermethrin and beta-cypermethrin + chlorpyrifos. In the second study (Deng & Shi 2007), mortality 24 h after sprays were applied was: > 95% for imidacloprid + isoprocarb, and carbosulfan; 90% to 94.9% for isoprocarb and carbosulfan; 30.8% for buprofezin; and < 30% for methomyl, rotenone, 'petroleum oil', abamectin and calcium polysulfide. Control with the imidacloprid + isoprocarb cocktail was

not enhanced when the pesticides were applied in 'petroleum oil'. Deng & Shi (2007) claimed that effective management of HLB requires psyllid mortality 24 h after application of pesticides to be > 95%. The authors of this document have observed use of cocktails with up to four active ingredients, including methamidaphos and monocrotophos, being used for the control of *D. citri* in Asia, particularly in Thailand

Based on recent evaluations in Florida, Rogers (Draft California Action Plan for Huanglongbing and *Diaphorina citri*, in prep., November 2007) ranked the following chemicals in descending order of efficacy for their impact on adult psyllid mortality: +++ carbaryl, +++ chlorpyrifos, +++ cyfluthrin, fenpropathrin, lambda-cyhalothrin, zeta-cypermethrin, +++ imidacloprid, thiamethoxam, ++ abamectin, ++ spiromesifen, + mineral oils, kaolin. He noted that some broad spectrum pesticides such as organophosphates, carbamates, pyrethroids and neonicotinoids had a high level of efficacy against *D. citri* but that every chemical within these classes was not effective. For example, for neonicotinoids, imidacloprid was very effective, but acetamiprid was not.

Qureshi & Stansly (2007) reported three experiments in which they evaluated soil applications of thiamethoxam and imidacloprid in water suspensions, imidacloprid and oxamyl as soil drenches, and foliar applications of several pesticides in two field trials in which a low-profile airblast sprayer was used to apply sprays at 1,400 L/ha. The studies were undertaken in summer in Florida. In the first spray trial, 0.004% acetamiprid and 0.004% imidacloprid were compared for control of *D. citri* on 12 year-old sweet orange trees. Outcomes were assessed 3, 7 and 14 days after treatment. Nymphal populations declined naturally over the 14 days. Neither treatment was particularly effective, though imidacloprid was better than acetamiprid. The average number of nymphs per flush over the 14-day sampling interval was 40% lower in the imidacloprid treatment (11.48 compared to 19.58). The sprays appeared to suppress ladybird activity. In the second spray trial, foliar applications of an 2.25% nC23 HMO, and 0.01% diflubenzuron in 2.25% HMO, 0.16% pyridaben, 0.025% metasystox, 0.004% and 0.005% spirotetramat, 0.1% spiroticlofen and 0.008% imidacloprid for control of *D. citri* infested 12 year-old sweet orange trees. All sprays were applied once at 1,400 L/ha using a low-profile airblast. Impacts were assessed on three occasions over 18 days. With the exception of pyridaben all spray treatments significantly reduced nymphs 3 days after treatment, but differences at 10 and 18 days were not significant. The authors did not comment on the possible impact of aging populations and flushes on the results, but mean numbers nymphs in the untreated control were 6.33, 0.49 and 0.32 per flush 3, 10 and 18 days after treatment.

In the soil application trial, both thiamethoxam and imidacloprid were applied at about 0.23% in about 240 mL of water poured onto the ground, within 30 cm of the trunk, at the base of each treated 3 year-old Valencia sweet orange tree (Qureshi & Stansly 2007). Impacts were assessed 28, 37, 43 and 50 days after treatment. Average numbers of nymphs on immature flushes (feather to tender leaf stage) over the sampling interval were 80% and 46% lower, respectively, than in the control. In the soil drench trial, imidacloprid was applied once at about 1 mL ai/tree and oxamyl was applied twice, one month apart, at 3.4 and 6.8 mL ai/tree to 5 year-old Valencia trees. The chemicals were applied with an Eze-Dose CCI DO 35 applicator. Impacts were assessed 10, 21, 47, 60 and 68 days after the first applications. There were no significant differences between the oxamyl treatments and the untreated control for numbers of nymphs per flush. The differences between the imidacloprid treatment and the control were significant with overall suppression of about 80%: this was regarded as very effective. The same treatment reduced numbers of adult on the flushes by 90% over the same interval. Qureshi & Stansly (2007) concluded that the sprays they directed at eggs and nymphs provided some short-term benefit but that sustained activity by natural enemies appeared to provide better long-term control. They suggested that drench applications should be applied in spring rather than, as in their trials, in mid summer, and that foliar sprays be applied in winter for control of adult psyllids when detrimental impacts on beneficial insects would be less than in other seasons.

In two experiments in Florida (Qureshi & Stansly 2008) in which the carbamate, aldicarb¹⁸⁷, was applied to soil under 7 year-old sweet orange trees in spring (8 March) at 1.4 kg, 2.8 kg and 5.6 kg ai/ha, adult *D. citri* populations were reduced by 25-37%, 45-46% and 58-66% respectively compared with untreated controls. However, these impacts were based on assessments some 80 and 100 days after treatment and no significant differences were recorded when observations were made 6 and 40 days after treatment in the first experiment and 8 days after treatment in the second experiment. In another experiment, application at the 5.6 kg ai/ha (the maximum legal rate in Florida) in mid-winter reduced adult populations by 86%, and applications at this rate in spring reduced shoot infestations by 77%. Use of aldicarb in Florida citrus orchards is usually restricted to the interval from 1 January to 30 April, during the winter-spring dry season, in order to reduce leaching of the pesticide through sandy soils into watertables. The authors (Qureshi & Stansly 2008) noted that spiders and ladybirds were equally abundant on treated and untreated trees.

Rao et al. (2008) found the benzoylphenyl urea insect growth regulator novaluron as a 10 EC formulation to be more effective than a 30 EC formulation of dimethoate against second instar nymphs of *D. citri*, when sprays were applied to infested lime and lemon seedlings.

Neem and other botanical derivatives. Chakravarthy et al. (1998) reported high levels of control (> 96%) seven days after *D. citri*-infested sweet orange trees were sprayed separately with 0.0003% azadirachtin and 1% neem oil. Rao et al. (2008) reported that azadirachtin (1% formulation), neem oil, and an extract of sweet flag (*Acorus calamus* L. [Acorales: Acoraceae]) were less effective than a 30 EC formulation of dimethoate against second instar nymphs of *D. citri*, when sprays were applied to infested lime and lemon seedlings.

Mineral oils. Crude oils, from which mineral oils (petroleum sprays oils¹⁸⁸) are refined, were recommended for control of *D. citri* by Fletcher (1917, 1919), Husain & Nath (1927), and by Pruthi & Mani (1945). No data were reported to support these recommendations and Rae et al. (1997) were the first to report the impact of mineral oils. In an experiment in which adult psyllids were released onto potted calamondin (*C. × microcarpa* Bunge) after they were sprayed with treatments involving water and aqueous emulsions of 0.25%, 0.5%, 0.75% and 1% v/v Caltex Lovis (an nC22 horticultural mineral oil: HMO), they observed that oviposition on flush growth and nymph survival declined as oil concentration increased. In another experiment, Lovis sprays applied to eggs and nymphs on fresh calamondin flush maintained in water-filled flasks, mortality of eggs and nymphs increased with increasing concentrations of oil (0% to 1%) and the order of declining susceptibility was first and second instar, then third to fifth instar nymphs, then eggs. In a third experiment, psyllids were released initially onto potted calamondin trees after they were sprayed with either water, nC22 Caltex Lovis, nC23 Ampol D-C-Tron NR (both at 0.5% v/v), an nC27 machine oil (0.5%), an organophosphate (omethoate at 1 g ai L⁻¹) and an insect growth regulator (diflubenzuron at 0.1 g ai L⁻¹) and then again after the treatments were applied on a second occasion 5 days after the first. Psyllid populations in the oil, omethoate and diflubenzuron treatments nine days after the second application of sprays were significantly lower than in the control, but differences between the oil, omethoate and diflubenzuron treatments did not differ significantly. The effect of the oil deposits oil sprays was attributed to oviposition sprays and egg and nymph mortality.

Olfactory responses of *D. citri* females to oil deposits have been studied in a controlled environment facility at Universitas Gadjah Mada (UGM) in Java, Indonesia. These studies showed that *D. citri* adults could detect mineral oil volatiles from mandarin leaves dipped in 2% aqueous emulsions

¹⁸⁷ Aldicarb is one of the most acutely toxic pesticides to vertebrates, including humans (Cox 1992).

¹⁸⁸ For comprehensive information on the chemistry and classification of mineral oils (petroleum spray oils), and their use in agriculture and horticulture, see Beattie GAC, Watson DM, Stevens ML, Rae DJ, Spooner-Hart RN (eds). 2002. Spray Oils Beyond 2000. University of Western Sydney.

(Mofit Poerwanto, UGM, pers. comm.). When given a choice to move towards oil or towards water dipped leaves, some 60% of adults (1:1 sex ratio) did not move in the oil treatments compared to 22% in the controls. When given a choice of leaves dipped in either an *n*C23 HMO or an *n*C24 AMO, some 42% of adults did not move in either treatment. When given a choice between oil treated leaves and a treatment comprising an untreated leaf + piece of oil treated filter paper, more than 52% of adults did not move towards the treated leaves compared to less than 30% in the other treatment. When presented with a choice of no stimulus (no leaf, filter paper or oil) and an untreated leaf, > 65% of adults did not move towards the former compared to about 20% in the latter. Lastly, when treatments comprising water-dipped leaves plus filter papers dipped in emulsions of either of the two oils oil were compared with water dipped leaves, some 30% of adults did not move in the oil treatments compared to about 15% in the other treatment with just water dipped leaves. These results suggest that adult *D. citri* can detect oil volatiles (possibly more readily from deposits on leaf surfaces than on paper) and that this leads them to avoid oil treated surfaces for feeding and oviposition. Alternatively, application of oils to leaves may lead to (a) suppression of plant volatiles that attract *D. citri* adults or (b) to the release of plant volatiles that they avoid. Detection of volatiles appears to be through antennal olfactory receptors.

Field studies on the use of mineral oils have been reported by Leong et al. (2002) and Leong (2006). Leong et al. (2002) compared the impact of three spray programs on *D. citri* populations, and a suite of other citrus pests, in each of three orchards near Kuching in Sarawak, Malaysia, over 11 consecutive months in 1998-1999: an initially pathogen-free, bud-grafted, non-bearing honey tangerine (*C. × aurantium*) orchard; a bearing, marcotted, honey tangerine orchard; and a bearing, marcotted, langkat mandarin (*C. reticulata*) orchard. These orchards were < 2 years, 6 years, and 4 years old respectively in 1998.

The three spray programs were applied from July 1997:

- an *n*C24 HMO (Ampol D-C-Tron Plus);
- a Sarawak Department of Agriculture (SDOA) synthetic pesticide program; and
- a common farmer program (FP).

The HMO was applied at 0.33%–0.5% (v/v) (mostly 0.5%) at all locations. All synthetic pesticides were applied at the manufacturers' recommended rates.

In the non-bearing tangerine orchard, applications of imidacloprid (0.01%) alternated with chlorpyrifos (0.02%) or deltamethrin (0.0025%) in SDOA program, and triazophos (0.03%) alternated with a proprietary mix of cypermethrin (0.125%) and chlorpyrifos (0.0125) in the FP.

In the bearing orchards, deltamethrin alternated with chlorpyrifos in the SDOA program. In the bearing mandarin orchard, triazophos alternated with the cypermethrin/chlorpyrifos mix in the FP; and in the bearing tangerine orchard, prothiofos (0.1%) alternated with the cypermethrin/chlorpyrifos mix.

Sprays in the non-bearing orchard were applied weekly to runoff. Each bearing mandarin tree was sprayed with 2–3 L of spray on each occasion, but coverage was less effective than in the non-bearing tangerine orchard. Each tree in the bearing tangerine orchard was sprayed with 5 L of spray on each occasion, and coverage was not as effective as in the other 2 orchards.

All control programs were similarly effective against *D. citri*, citrus leafminer, armoured scales, including red scale and mussel scale (*Lepidosaphes beckii* (Newman) [Hemiptera: Diaspididae]), and whitefly (*Aleurocanthus* sp. [Hemiptera: Aleyrodidae]). The HMO program was not as consistently effective against black citrus aphid and citrus mealybug (*Planococcus citri* (Risso) [Hemiptera: Pseudococcidae]) as the pesticide programs, but it was more effective than these

programs against chilli thrips (*Scirtothrips dorsalis* Hood [Thysanoptera: Thripidae]), citrus red mite (*Panonychus citri* (McGregor) [Acari: Tetranychidae]) and citrus rust mite (*Phyllocoptura oleivora* (Ashmead) [Acari: Eriophyidae]).

Leong (2006) reported additional results for the youngest honey tangerine orchard mentioned by Leong et al. (2002). In this instance the results were reported for an interval of 23 months during 2000-2001. The treatments were similar to those reported by Leong et al. (2002). An unsprayed control was compared with weekly applications of 0.35% (v/v) sprays of the *n*C24 HMO, a spray program based on triazophos (0.03%) alternating with the above mentioned cypermethrin/chlorpyrifos mix, and a spray program based on imidacloprid (0.01%). All sprays were applied thoroughly to runoff every 6-7 days during peak psyllid activity during flush cycles. The HMO treatment was as effective, or more effective, for suppressing *D. citri* populations than the synthetic pesticide treatments. It had significant impacts on reducing oviposition and feeding (Leong 2006).

Spread of HLB in this orchard from 1998 to October 2001 was also reported by Leong (2006). From zero in the pathogen free trees when they were planted in 1997, levels of infection rose quite rapidly over the next 4 years in the unsprayed control and less rapidly in the other treatments. Increases in the HMO and imidacloprid treatments were similar and less rapid than in the triazophos/cypermethrin/chlorpyrifos treatment. Symptoms resembling HLB were present in 80% of control trees in October 2001, and in 40%, 33% and 65% of trees in the HMO, imidacloprid, and triazophos/cypermethrin/chlorpyrifos treatments respectively. Levels of HLB as determined by PCR were 42%, 11%, 9% and 23% respectively. Three major flush growth cycles occurred annually in the orchard (Leong 2006).

Childers & Rogers (2005), in addition to experiments in which they compared the impact of abamectin, acetamiprid, chlorpyrifos, fenpropathrin, imidacloprid, spinosad and thiamethoxam on populations of *D. citri* (see above), also compared mineral oils applied with a 'pul-Tank' sprayer at 2,338 spray L/ha for their impact on psyllid populations in two experiments. In the first instance, sprays were applied when the mean number of adults was 5.6 per flush: in the second when the mean number of adults was 2.5 per flush. In the both instances, the oils were two *n*C23 HMOs, an *n*C24 agricultural mineral oil (AMO), and *n*C25 AMO. Three of the oils were applied at 2%, and one, one of the *n*C23 oils, was applied at 0.8% alone, and at 0.8% with either an alkylsilicone wetter or a mineral-oil based surfactant added. Impacts were assessed 5, 9 and 13 days after the application of sprays in the first experiment and at 5, 12 19 days after treatment in the second. None of the treatments was effective over either 13 or 19 days. The authors (Childers & Rogers 2005) compared their results with those of Rae et al. (1997), Huang et al. (2002) and McKenzie et al. (2004), noting some differences in spray equipment, oil concentrations and frequency of sprays, but not fundamental differences in strategies and timing of sprays.

McKenzie et al. (2004) and Childers & Rogers (2005) applied sprays to immature flushes infested with adults, nymphs and eggs, and the current threshold for application of insecticide sprays for control of *D. citri* in Florida is 20% of young flush infested with adult psyllids (Rogers 2008: <http://citrusbmp.ifas.ufl.edu/Workshop%20Presentations/Psyllid%20IPM.pdf>). This recommendation is based on the premise that adults are easier to kill than eggs and nymphs. However, it increases the probability of infected nymphs becoming adults, and then dispersing and transmitting the pathogen.

Rae et al. (1997), as noted above, reported effects of HMOs and a machine oil on oviposition by *D. citri* females and survival of the immature stages. Huang et al. (2002) reported impacts of 6-10 applications of 0.5% *n*C24 HMO sprays on range of pests in five provinces in China. Their studies were related to those reported by Leong et al. (2002) in Sarawak, Malaysia (see above). Application

of multiple low-concentration ($\leq 0.5\%$ v/v) mineral oil sprays applied to run-off by these authors stemmed from studies by Beattie et al. (1995) on citrus leafminer that were undertaken with the aim of applying an *n*C21 HMO to minimise oviposition on immature leaves from the point when buds began to open: a prophylactic strategy based on host-phenology rather than a strategy based on pest abundance, and one pertinent to both *P. citrella* and *D. citri*.

The study was undertaken in a nursery in the Sydney region where citrus leafminer populations increase rapidly and exponentially in late summer from virtually undetectable levels that occur from winter to mid summer. The sprays were applied on 7 occasions to immature flush growth at 5-7 day intervals from 10 February (late summer) to 22 March (early autumn). They (Beattie et al. 1995) found the oil significantly reduced oviposition by citrus leafminer when applied at concentrations as low as 0.125%.

Subsequent studies, in which 4, 0.5% sprays of an *n*C23 HMO were applied weekly at 3,500 L/ha to 4-m high lemon trees near Sydney from early January to early February, before and during the initial phase of exponential population growth, significantly reduced levels of infestation (Liu et al. 1997). Studies in this region from 1993 to 1995 indicated that the initial detectable increase in abundance of citrus leafminer was related to an increase in the percentage of flushes infested in January and February, whereas increasing abundance from this point was related to an increase in the percentage of leaves infested within flushes and number of mines per leaf. The fits of frequency distributions indicated that populations were highly contagious initially and became random as populations increased (Liu 1997). Such trends also occur for *D. citri* (Wang 1981, Leong 2006) and are reflected in initially contagious distributions of HLB following natural ingress into orchards (Gottwald et al. 2007).

Although, mineral oils have been widely used as adjuvants to improve efficacy of insecticides and fungicides through enhanced deposition, persistence and uptake (Rae 2002) there are no reports¹⁸⁹ of such use with insecticides for the control of *D. citri* or *T. erythrae*. In her comprehensive review, Rae (2002) noted that in 260 of 358 (73%) instances the efficacy of the active ingredients applied with oil was enhanced. There were only 21 instances in 358 (6%) in which activity of the active ingredients was not enhanced. For scales, aphids and whiteflies, mineral oils enhanced the activity on insecticides in 24 of 41 instances and only reduced effectiveness in 2 of the 41 instances. The insecticides included organophosphates, systemic carbamates, pyrethrins, insect growth regulators and abamectin. One report noted an increased efficacy of diflubenzuron against pear psylla, *Cacopsylla* (syn. *Psylla*) *pyri* (L.) [Psyllidae]. For mites and fungal pathogens of plants, 50% and 71% of outcomes, respectively, were enhanced when products were applied with oil.

Zabkiewicz (2002) also reviewed literature on enhancement of pesticide activity by oil adjuvants, dealing with retention, uptake and translocation of active ingredient. Gaskin et al. (2002) presented information demonstrating enhanced spread of droplets of mineral and plant oil formulated with 5% alkylsilicones, in lieu of conventional non-ionic emulsifiers, on leaf surfaces and improved efficacy of 1% aqueous emulsions of both types of oils against two-spotted mite (*Tetranychus urticae* Koch [Acari: Tetranychidae]) adults and lightbrown apple moth (*Epiphyas postvittana* (Walker) [Lepidoptera: Tortricidae]) larvae. These other reports cited by Gaskin et al. (2002) suggest that it may be possible to use alkylsilicones to enhance efficacy of mineral oils against *D. citri* and a wide-range of other pests.

Given direct effects of mineral oils on *D. citri*, their use to enhance the efficacy of many insecticides, acaricides and fungicides, and their efficacy alone against scales, mites, whiteflies, leafminers and fungal pathogens, it appears that use of these oils at 0.25% to 0.5% should be an

¹⁸⁹ Rae et al. (1997) and Childers & Rogers (2005) tested abamectin in mineral oil for control of *D. citri*, but they did not test abamectin alone.

important component of management programs for *D. citri*, with the concentration of related to frequency of application and the host plant phenology.

Particle films. Particle films, kaolin-based hydrophilic white, nonabrasive, fine-grained aluminosilicate particles, have been used to alleviate tree stress and sunburn of fruit in warm dry environments¹⁹⁰ and recently evaluated as a physical means of suppressing insect pests¹⁹¹, including *D. citri*, most recently by Hall et al. (2007). According to Hall et al. (2007), McKenzie et al. (2002) showed that deposits suppressed infestations of *D. citri* nymphs and adults by 31% and 61% over a 2-week interval after application. In laboratory studies, Hall et al. (2007) showed that:

- a 3% (w/v) suspension in water was not acutely toxic when applied directly to eggs, older nymphs or adults;
- the presence of the dried particle film on leaves interfered with the ability of adults to grasp and walk on citrus leaves?
- during 30-s intervals, adults spent an average of 5 s moving on leaves with particle film compared with 16 s on leaves without film; and
- when leaves were inverted, a significantly higher percentage of adults fell, or flew, from treated leaves (53%) than untreated leaves (16%) (Hall et al. 2007).

In a field study in a sweet orange orchard over 12 months, these authors found that 3% w/v sprays applied to runoff on 13 occasions, at fairly regular intervals, reduced adult populations on mature and immature leaves by 78% and 60% respectively, and numbers of eggs and nymphs by 85% and 78% respectively. The impacts were reduced by rain (Hall et al. 2007). Possible impacts of the dust-like deposits of kaolin disrupting the effectiveness of natural enemies of a range of pests were raised (Hall et al. 2007), as dust is known to disrupt biological control of a range of pests (De Bach 1979), and Markó et al. (2008) reported that treatments promoted severe woolly apple aphid (*Eriosoma lanigerum* (Hausmann) [Hemiptera: Aphididae]) by reducing the abundance of polyphagous predators. Markó et al. (2008) also mentioned disruption of natural control other pests, and reduced parasitism of the apple sawfly (*Hoplocampa testudinea* (Klug) [Hymenoptera: Tenthredinidae] by *Lathrolestes ensator* (Brauns) [Hymenoptera: Ichneumonidae]. Kaolin (Surround) was highly effective at preventing citrus thrips populations from reaching damaging levels in Arizona lemons (Kerns & Wright: http://ag.arizona.edu/pubs/crops/az1178/az1178_3.pdf).

Particle films therefore have potential for use in management programs for *D. citri*, and presumably *T. erytrae*, but their impact on beneficial insects, though possibly less disruptive than many synthetic insecticides, will need to be considered.

Spray application. Efficacy of sprayers used for management of phytophagous arthropods varies considerably. They range from simple bucket pumps, through knapsacks of various types (hand, pressure and motorised), and stationary motorised units with long hoses, to drive-past airblast (with and without towers), rotary atomiser and oscillating boom (with or without outriggers) sprayers. Aircraft are also used in some countries, and boat-mounted airblast and booms are used in canals in delta regions in Southeast Asia. They have not been adequately evaluated for control of either *D. citri* or *T. erytrae*. No dose-response relationships have been derived (e.g., adult psyllid mortality versus volume of spray per hectare for any given concentration of active ingredient). The few studies that have been undertaken with citrus pests suggest that some drive-past sprayers are far more efficient than others. For example, oscillating booms are generally more effective for control of red scale, pink wax scale and hard wax scale (*Ceroplastes sinensis* del Guercio) with mineral oils than low-profile airblast sprayers, with results suggesting steep dose-response relationships for

¹⁹⁰ Glenn DM, Puterka G. 2004. Particle film technology: an overview of history, concepts and impact on horticulture. ISHS Acta Horticulturae 636: 509-511.

¹⁹¹ Glenn, D M, Puterka GJ, Vanderzwet T, Byers RE, Feldhake C. 1999. Hydrophobic particle films: a new paradigm for suppression of arthropod pests and plant diseases. J. Econ. Entomol. 92: 759-771.

booms and shallower responses for the low-profile airblasts (Beattie & Kaldor 1990, Beattie et al. 1991, 2002). Such relationships have not been derived for other pests or for synthetic pesticides.

Comparisons based on spray deposition on water or oil sensitive papers give some indication of comparative efficacy but they do not provide adequate information about levels of control. Deposition requirements depend on the targeted pest and its degree of mobility, the nature of the chemical applied (e.g., contact or systemic synthetic insecticides, or mineral oil), the modes of action of these chemicals (e.g., poisons, suffocants or repellents).

The nature of recommendations for amounts of pesticides to be used for control of pests also varies. In Australia, registrations for pesticides used in citrus orchards are based on quantities of formulated product or active ingredient per 100 L of water. Volumes of spray per hectare or unit row area are generally recommended, and if not, generally assumed to be to run-off. In the United States of America (USA) recommendations are generally based on amounts of active ingredient per acre with limited variation to account for sprayer type or performance. Recommendations for control of citrus pests in the USA also tend to emphasise low (e.g., 2,300 L ha⁻¹), even very low (e.g., 140 L ha⁻¹ with drivepast sprayers and < 93 L ha⁻¹ with aircraft), spray volumes, on the apparent assumption that outcomes of low and high volume sprays are similar, providing the amount of active ingredient per acre is the same. Fogging is being tested, but at this point it has not been approved for use in commercial production (Phil Stansly, University of Florida, pers. comm., October 2008).

Large-scale trials will be required to evaluate the effectiveness of selected chemicals and sprayer-types if *D. citri* becomes established in Australian citrus orchards. The emphasis will need to be on deriving dose-response relationships for 2 or more concentrations of each product, for each sprayer type. At this point, the most effective sprayers are likely to be oscillating booms, and the most recent air-assisted sprayers developed by Geoff Furness, South Australia Research and Development Institute, Loxton, South Australia. Low-profile airblast sprayers, as used by most Australian citrus growers, are unlikely to be effective and they may, given high air movement and turbulence associated with their use, aid dispersal of the psyllid by blowing adults into wind currents above trees.

Khangura & Singh (1984) showed that the type of high volume and ultralow volume sprayer (with or without blower) affected the effectiveness of low volume concentrate and emulsifiable concentrate formulations of dimethoate applied at 0.5 L ai/ha for the control of *D. citri* on citrus. Percentage reductions in psyllid populations when applications were made with a hand-held battery-operated spinning-disc ULV sprayer with a blower (Turbair Sprite), a motorised knapsack sprayer (MKS), and a foot sprayer were 89-99%, and significantly higher than reductions (78-85%) obtained when applications were made with a hand-held battery-operated spinning-disc ULV sprayer (Fogair) without a blower. Use of the first 3 sprayers resulted in > 50% mortality for up to 18, 14 and <14 days after treatment, respectively. Irrespective of type of sprayer, the mortality of the pest was 74-95% on the windward side of the tree as compared with 59-74% on the leeward side (Khangura & Singh 1986). For the Fogair sprayer that was not fitted with a blower, mortality was 55-88% on the windward side as compared with 9-41% on the leeward side. No significant differences between effectiveness in this respect were observed for the two sprayers with blowers. The location of the pest on the tree also affected the performance of the compound (Khangura & Singh 1986)¹⁹².

Timing and frequency of chemical treatments. Recommendations and strategies for application of pesticides to foliage, trunks and soil have historically focused on killing *D. citri* eggs, nymphs

¹⁹² For additional information see: Khangura JS, Singh H. 1985. Effect of ULV sprayers on the efficacy and persistence of low dosages of dimethoate LVC for the control of citrus psylla (*Diaphorina citri* Kuwayama). Indian Journal of Horticulture 42(3/4): 299-303.

and adults during 'critical' periods of high psyllid activity on seasonal flushes (see Aubert 1980, 1990c), particularly during hot dry periods (Aubert 1990b). Husain & Nath (1927) mentioned that one thorough spraying with 'rosin compound'¹⁹³ in winter killed most adults, and that two sprays were required if winter applications were less than thorough, and sometimes in spring, with up to three applications being required, a week or so apart, per flush cycle before the emergence of a new brood of adults. They emphasised the importance of timing and mentioned that tobacco decoction¹⁹⁴ gave very good results. Pruthi & Mani (1945), quoting other authors, stated that spraying adults, with presumably tobacco decoction, rosin or crude oil emulsions, was not profitable as the adults were capable of flying away. They considered spraying more effective against nymphs. These recommendations and comments were made before it was known that HLB was transmitted by *D. citri*. In Asia, particularly Thailand, sprays have been applied far more frequently since then.

Aubert (1990c) mentioned application of 40 to 45 sprays per year by Thai farmers. Some Thai farmers applied sprays weekly in the 1980s (pers. comm.). da Graça (1991) mentioned that weekly monocrotophos sprays did not prevent transmission of HLB by *T. erytrae*. Catling (1968) was alarmed by the intensive pest control programs used in the Philippines in the 1960s and mentioned two large estates where combinations of insecticides including the organochlorines, endrin and lindane, and the organophosphates, parathion and EPN, were applied fortnightly. Ko (1991) mentioned that sprays were required at least fortnightly in Malaysian orchards for control of *D. citri*, and that more frequent applications were required during periods of flush growth. Current management strategies in Brazil involve annual applications of some 8-18 sprays and 1-3 systemic insecticide applications to trees less than 4 years old, and fogging of mature trees, more than 5 years old, 4-5 times annually plus 4-7 insecticide sprays (Rogers 2008: <http://citrusbmp.ifas.ufl.edu/Workshop%20Presentations/Psyllid%20IPM.pdf>). The effectiveness of these programs in preventing spread of HLB is governed by distances between orchards, levels of control achieved in neighbouring orchards and, most importantly emphasis placed on detection and removal of HLB infected trees (Juliano Ayres, Fundecitrus, pers. comm., April 2008; Lopes et al. 2008).

Most emphasis has been on killing psyllid eggs, nymphs and adults on mature leaves (e.g. Husain & Nath 1927) or during flush cycles (Aubert 1988a). Current strategies for *D. citri* in Florida (Rogers 2008: <http://citrusbmp.ifas.ufl.edu/Workshop%20Presentations/Psyllid%20IPM.pdf>) recommend application of sprays to control adults when they are present on 20% of new flush is infested, as control killing eggs and nymphs is considered more difficult. Such strategies are bound to enhance, rather than reduce, spread of HLB.

The focus on killing the psyllids in order to limit the spread of HLB has led to limited emphasis being placed on reducing their impact by minimising feeding by adults, and oviposition. Likewise, for strategies to prevent exponential growth that the psyllid populations, particularly those of *D. citri*, exhibit in well-watered and fertilised orchards, and on ornamental *Murraya* plants. Nor have strategies involving such preventative or prophylactic treatments been tested in conjunction with strategies based on killing adults between or within flush cycles. However, some recommendations in Asia (Rae et al. 2006, Yang et al. 2006) have, based on studies reported by Rae et al. (1997), Leong et al. (2002) and Leong (2006), recommended use of mineral oils and contact and systemic pesticides such as imidacloprid.

¹⁹³ Rosin comprises solid resins from pines and some other plants, including conifers. The stock solution for sprays recommended by Husain & Nath (1927) was prepared with 20 kg rosin, 10 kg soda and 18 L of water, prepared by adding sufficient water to a vessel to cover the rosin and soda, heating the mixture over a slow fire and letting the mixture boil until the rosin and soda dissolve, and adding the remaining water slowly until the mixture is cooked, when a drop placed in water did not form a milky emulsion. The solution was then mixed with 6 parts clean water and 10 kg of solignum or 'sanitary fluid' (a coal tar-based disinfectant) added: 4.5 L was sufficient to spray one tree.

¹⁹⁴ Stock solutions, prepared by soaking 0.9 kg tobacco refuse (leaves, stems dust et.) in 4.5 L water for 24 hours, straining and adding 0.22 kg cheap soap, diluted in 8 parts water.

Biological control

Parasitoids and predators. There are two primary parasitoids of *D. citri*: the ectoparasitoid *Tamarixia radiata*¹⁹⁵ (Waterston) [Hymenoptera: Eulophidae] by Waterston (1922) and the endoparasitoid *Diaphorencyrtus aligarhensis*¹⁹⁶ (Shafee, Alam & Agarwal) [Hymenoptera: Encyrtidae] by Shafee et al. (1975). Neither occur in Australia. In addition to *D. citri*, hosts of *D. aligarhensis* apparently include *Diaphorina cardiae* Crawford), *Diaphorina auberti* Hollis and *Psylla* sp. (Tang & Aubert 1990: *Diaphorina cardiae* is a junior synonym of *Diaphorina aegyptiaca* Puton (Burckhardt 1984). Eggs of the primary parasitoids are laid on (*T. radiata*) and in (*D. aligarhensis*) immature stages of their host. After the eggs hatch, the immature stages (larvae) of the wasps develop as larvae until they pupate. This leads to death of psyllid nymph. Adult wasps emerge from the pupae sometime later, with *T. radiata* adults leaving an exit hole in the thorax of the mummified body of its host, and *D. aligarhensis* leaving a exit hole in the abdomen of the mummified host. The effectiveness of both primary parasitoids is affected by a number of hyperparasitoids, the identities of which vary between regions (Waterhouse 1998, Halbert & Manjunath 2004). *T. radiata*, spiders and the ladybird *Cheilomenes sexmaculata* (Fabricius) are on common *D. citri*-infested *Murraya 'paniculata'* plants in Guangzhou in summer (GACB, pers. obs., 2007-2008). Inoculative releases of *T. radiata* (Waterston) on jasmine orange in Taiwan successfully keep *D. citri* reservoir populations at low levels (Chien et al. 1989, Chien 1991).

Michaud (2004) regarded ladybirds as the most important biological control agents of high-density *D. citri* populations in central Florida. In field trials in which insecticides were evaluated for control of *D. citri* in Florida, Qureshi & Stansly (2007) noted that natural control appeared to be more effective in the long-term than foliar applications of the sprays that they applied at 1,400 L/ha with an airblast sprayer¹⁹⁷.

Sandana (1991) described the hunting behaviour the spider *Marpissa tigrina* Tikader [Araneae: Salticidae] and its functional response to *D. citri* in the laboratory. The predation rate peaked at consume up to 17 nymphs per day when 40 nymphs available. Average consumption of prey fell from 100% to 20% per day as the number of prey increased from 10 to 70. The author concluded that *M. tigrina* could be exploited for control of the psyllid in orchards.

T. erytrae also has two primary parasitoids, the ectoparasitoid *Tamarixia dryi* (Waterson) and the endoparasitoid *Psyllaephagus pulvinatus* (Waterston), and 13 secondary and tertiary hyperparasitoids are associated with the psyllid (McDaniel & Moran 1972, Prinsloo 1980, Aubert & Quilici 1984). *T. dryi* lays its eggs singly beneath the third, fourth or fifth instar nymphs. The larva sucks out the body contents of the nymph and when fully grown binds the remains of its dead host with filaments to the edges of the leaf gall. *P. pulvinatus* is mainly active towards midsummer (Catling 1972). Both primary parasitoids have considerable impact in controlling the numbers of their host, *T. erytrae* (McDaniel & Moran 1972). van der Merwe (1941) reported that as many as 75% of more advanced nymphs may be parasitised. Catling (1969b) recorded that during periods of favourable synchrony at least 40-50% of the susceptible stages were parasitised, and that under conditions of poor synchrony parasitism frequently dropped below 10%. The impact of the hyperparasitoids ranges little apparent significance (Catling & Annecke 1968) to being at least partly responsible for high population levels of the psyllid (McDaniel & Moran 1972). Aubert & Quilici (1984) note that the biology of *T. dryi* was similar to that of *T. radiata*, and that the biology of *P. pulvinatus* seemed to be very similar to that of *D. aligarhensis* noting, however, that the adults

¹⁹⁵ syns *Tetrastichus radiatus* Waterston (Waterston 1922, Graham 1969, Tang 1990, Tang & Aubert 1990, Waterhouse 1998) and *Tetrastichus indicus* Khan & Shafee (Hayat & Shahi 2004).

¹⁹⁶ syns *Aphidencyrtus aligarhensis* Shafee, Alam & Agarwal, *Aphidencyrtus diaphorinae* Myartsera & Tryapitzyn and *Psyllaephagus diaphorinae* Lin & Tao (Noyes & Hayat 1984, Prinsloo 1985, Tang 1990, Tang & Aubert 1990, Waterhouse 1998).

¹⁹⁷ Higher volumes may have resulted in more effective control.

of *P. pulvinatus* can emerge from the underside of the *T. erytrae* nymph or chew a hole through the thorax of the mummy.

van der Merwe (1923), Catling & Annecke (1968) and Catling (1970d) observed several unidentified spider species preying on *T. erytrae*. van den Berg et al. (1987a) observed thirteen species of spiders preying on adult citrus psylla and they expressed the opinion that spiders are possibly the most important predators of this pest. van den Berg et al. (1992a) recorded 21 families of spiders were sampled in an unsprayed citrus orchard in South Africa. Numerically the Salticidae was the dominant family (34.4 %) followed by the Theridiidae (21.9 %), Thomisidae (11.9 %), Araneidae (7.9 %), Clubionidae (7.0 %) and the Tetragnathidae (3.7 %). Eighteen species of spiders were observed to prey on *T. erytrae* while 6 species were observed to trap nymphs and adults under their retreats and webs. There were significant positive correlations between the weekly psylla populations and the weekly populations of web-building spiders and wandering spiders present one to four weeks later but no significant correlation between the weekly spider populations and the weekly psylla populations present one to five weeks later. The authors (van den Berg et al. 1992a) summarised the predatory behaviour of the spiders and impact of web type on the psyllid. They concluded that while the spiders were unable to keep psyllid populations at acceptable low levels, they may have contributed in reducing psyllid populations.

In Australia, predators of *D. citri* and *T. erytrae* are likely to include:

- ladybirds [Coleoptera: Coccinellidae]
 - transverse ladybird *Coccinella transversalis* Fabricius
 - common spotted ladybird *Harmonia conformis* (Boisduval)
 - variable ladybird *Coleophora inaequalis* (Fabricius)
 - yellow-shouldered ladybird *Scymnodes lividigaster* (Mulsant)
 - netty ladybird *Harmonia testudinaria* (Mulsant)
 - minute two-spotted ladybird *Diomus notescens* (Blackburn)
 - steelblue ladybird *Halmus chalybeus* (Boisduval)
 - striped ladybird *Micraspis frenata* (Erichson)
- hover flies [Diptera: Syrphidae]
 - *Simosyrphus grandicornis* (Macquart)
 - *Melangyna viridiceps* (Macquart)
- lacewings [Neuroptera: Chrysopidae]
 - brown lacewing *Micromus tasmaniae* (Walker)
 - green lacewing *Oligochrysa lutea* (Walker)
 - green lacewing *Mallada signata* (Schneider)
 - *Plesiochrysa ramburi* (Schneider)
- flower bugs (Hemiptera: Anthocoridae)
 - *Orius tantillus* (Motschulsky)
- spiders [Araneae]
 - lynx spiders *Oxyopes* sp. [Oxyopidae]
 - huntsman spiders *Holconia* sp. [Sparassidae]
 - flower spiders *Diaea* sp. [Thomisidae]
 - jumping spiders *Opisthoncus* sp. [Salticidae]

Entomopathogens and biological pesticides. Subandiyah et al. (2000b) recorded two fungal entomopathogens, *Paecilomyces fumosoroseus* (Wize) A. H. S. Brown & G. Smith and *Hirsutella citriformis* Speare (Hypocreales: Clavicipitaceae) attacking *D. citri* in Indonesia and observed that healthy psyllid adults inoculated with conidia of the *P. fumosoroseus* died within 6 days. The pathogenicity of *H. citriformis* was not tested, as it was not easily cultured in artificial media.

Rivero & Grillo Ravelo (2000) reported *H. citrifomis* and two other fungi, *Beauveria bassiana* (Balsamo) Vuillemin [Moniales: Moniliaceae], *Lecanicillium lecanii* (Zimmerman) Gams & Zare (= *Verticillium lecanii* (Zimm.) Viégas) [Hypocreales: Clavicipitaceae], attacking *D. citri* in Cuba and. Etienne et al. (2001) reported that *H. citrifomis* was, under certain conditions, capable of regulating the populations of *D. citri* in Guadeloupe. Meyer et al. (2007a) reported a novel isolate related to *H. citrifomis* from mycosed adult *D. citri* observed during periods of high relative humidity in Florida. In laboratory bioassays, high levels of mortality were observed in *D. citri* that were exposed to the conidia-bearing synnemata produced *in vivo* and *in vitro*. Meyer et al. (2007b) noted that *H. citrifomis* penetrates the external surfaces of psyllids and grows in the haemolymph until the insect dies, but that *P. fumosoroseus* appears to use toxins to rapidly kill psyllids and apparently does not grow inside of the insect host. They also noted that psyllids infected with these pathogens exhibit dramatic changes in their behaviour: they have a reduced tendency to fly, and they twitch, shake and flick their wings prior to death.

Rao et al. (2008) compared the toxicity of several ‘biorational’ insecticides applied as sprays to second instar *D. citri* nymphs lime and lemon seedlings. Commercial formulations of spinosad (derived from the soil dwelling bacterium *Saccharopolyspora spinosa* Mertz & Yao [Actinomycetales: Pseudonocardaceae] and abamectin (derived from the soil bacterium *Streptomyces avermitilis* Burg et al. [Actinomycetales: Streptomycetaceae]) were more effective than dimethoate but sprays of the ectotoxins of the bacterium *Bacillus thuringiensis* Berliner [Eubacteriales: Bacillaceae] and the fungus *L. lecanii* were not. Although the authors concluded that spinosad was more toxic than abamectin, this was only true for the formulations (45 SC and 1.9 EC respectively): abamectin was actually the more toxic of the two active ingredients.

In their evaluations of the alkylsilicone wetters alone or with imidacloprid (see above), Srinivasan et al. (2008) also assessed the impact of the wetters on abamectin. Both wetters (Silwet L-77 Kinetic) at 0.05% enhanced activity of sprays applied directly to eggs and nymphs on potted trees but their residual activity against adults was generally insignificant. The study did not assess the potential of mineral oils, with or without either of the two alkylsilicones, to enhance the efficacy of abamectin or imidacloprid.

Repellent Intercrops and Groundcovers

Farmers in the Mekong Delta in southern Việt Nam often grow citrus with other types of fruit within their small holdings, which generally comprise < 1 ha. One such practice involves intercropping citrus with guava (*Psidium guajava* L. [Myrtales: Myrtaceae]), with the aim of gaining income annually from the guava trees for 3-4 years before the citrus trees produce fruit¹⁹⁸. During these years, the farmers may prune the guava trees to encourage bearing, and bag the guava fruit to reduce losses caused by fruit flies. From the third or fourth year they may then remove the guava trees or let them grow tall, while no longer encouraging them to bear fruit. Planting densities vary. During the 1990s, some farmers observed lower levels of HLB in guava interplanted citrus orchards than in orchards where only citrus was planted. This led to 2 unreplicated field experiments being undertaken by staff at the Southern Fruit Research Institute (SOFRI), My Tho, in the province of Tien Giang, within the delta. These experiments compared citrus planted with and without guava in ≤ 0.5 ha plots. By coincidence, newly planted guava trees were left within an experimental site established to compare the efficacy of insecticides and mineral oils for control of *D. citri*, as part of a SOFRI-Australian Centre for International Agricultural Research (ACIAR)

¹⁹⁸ Use of guava interplants was misreported by Spann et al. (2007). The article contained several inaccuracies about the impact of guava on ingress of HLB into orchards, impacts on *D. citri*, impacts on other pests and diseases, and the extent of use of mineral oils. Its focus was negative and missed the point: that reported observations in the Mekong Delta of Việt Nam indicated that interplanting with plants that produce volatiles that repel *D. citri*, or use of groundcovers for the same purpose, may be a viable alternative to use of pesticides. The claim that planting guava in a 1:1 ratio with citrus would reduce citrus yields by 50% is not apparent in the Mekong Delta, where, in the absence of guava many trees do not reach bearing age, or bear for only a few years (1-4).

project on HLB. King orange (*C. × aurantium*) trees at this 0.5 ha site were planted at distances of about 3 m on 4 raised beds surrounded by shallow canals in March 2004. Both the guava and king orange trees grew quickly, reaching 4-5 m within 3 years. In the second year, cajuput (*Melaleuca cajuputi* Powell [Myrtaceae]) trees were planted as windbreak and shade trees (to prevent sunburn on fruit) along the banks of the canals. These trees also grew rapidly.

In the two SOFRI experiments, populations of *D. citri* were dramatically lower in the presence of guava than in the absence of guava. Ingress of HLB was also dramatically lower (Le Quoc Dien, SOFRI, pers. comm.). In the ACIAR experiment, *D. citri* has been rarely observed and levels of HLB infection were about 20% in 2007 and 24% in 2008. Ingress of HLB was therefore slower than in the experiment with imidacloprid and fenobucarb reported (see above) by Gatineau et al. (2006), in which levels of HLB infection (symptomatic and PCR+) reached 24% and 74% respectively within 2 years, and 96% in the untreated control.

Additional reports and observations within a 17 year-old orchard in Tien Giang suggest that interplanting is particularly important in the first 3-4 years after an orchard is established. In this instance, the farmer removed the guava interplants some 3-4 years after the orchard was established. He has since maintained a management program based largely on the application of 0.5% mineral oil sprays some 8-12 times annually, mainly during flushing. In some instances, he has added imidacloprid to the oil (once per year) and in others he has applied the oil with abamectin. He also removes branches with symptoms of HLB, or HLB infected trees, but not, in some instances, before he harvests fruit after noticing leaf symptoms. A plausible explanation for the survival of these trees in the absence of guava 3-4 years after planting, may be related to several factors. Firstly, citrus trees in the region grow quickly and the trees are densely planted. *D. citri* adults, if present, would therefore be more common in upper canopies. Secondly, flushes become less abundant in relation to tree size as trees grow. Larger numbers of psyllids in proportion to canopy volumes would be attracted to younger trees, with more prolific flush growth, than to older trees flushing less prolifically. Thirdly, if infection occurs at the tip of an immature flush on a small tree (0.5 to 1 m tall) the pathogen would presumably multiply and spread more readily through such a tree than it would if infection occurred in the upper canopy of a larger, 5-6 m-tall tree. It seems that movement of the pathogen in a tree may be related to the rate it can multiply and move within phloem before the sieve elements it resides in cease to function as the phloem ages naturally before being incorporated into the outer bark. Thus, infection may be required on multiple occasions, and at several locations, before a tall tree succumbs to the disease. It seems that lateral movement within phloem may be rare. This hypothesis is supported by a simple experiment reported by Martinez (1973) in which branches were girdled and infected above or below the region from which bark was removed: over 10 months, the pathogen failed to move upward or downward through the girdled portion of the stems. It is also supported by observations that older trees are less prone to infection than younger trees (Lin 1963).

These reports, though in some instances anecdotal, indicate that interplanting citrus with guava in southern Việt Nam has the potential to provide farmers with income from guava fruit in the 3-4 years after planting before citrus trees bear, while simultaneously prolonging the viability of citrus orchards and significantly reducing expenditure on pesticides. Moreover, the observations could have major ramifications for the citrus industries of Southeast Asia, and more widely. Orchard-based evaluations have begun in Florida and China. However, it is likely that outcomes will depend on achieving and maintaining effective concentrations of volatiles within orchards. This will be more easily achieved in warm climates, where orchards are planted with windbreaks on flat land, than in hilly and windy regions.

Recent laboratory studies in China have shown that *D. citri* adults are repelled by guava leaf volatiles, in contrast to being attracted to *Citrus* and *Murraya* volatiles (Cen et al. 2008, Zaka et al.,

submitted). Results of the study reported by Zaka et al. (submitted) suggests that the effect of guava on *D. citri* is due to avoidance of guava volatiles, though it is possible that other factors, such as the masking of citrus volatiles and reduce visual recognition of host foliage may contribute to the response of the psyllid. A volatile fraction rich in sesquiterpenes (particularly α -selinene, δ -selinene, and β -caryophyllene) was obtained by supercritical fluid extraction by Sagrero-Nieves et al. (1994), and Ogunwande et al. (2005) identified 42 compounds in leaves after hydrodistillation (the most significant were limonene and β -caryophyllene). Idestein and Schreier (1985) identified 154 volatile compounds obtained by high-vacuum distillation from guava fruit: quantitatively, C6 aldehydes and alcohols were predominant. Some of these aldehydes and alcohols are the so-called 'green leaf volatiles' that have repellent effects on insects (Jang & Light, 1996). Further studies are required to determine whether any of the volatiles identified by Idestein and Schreier (1985), Sagrero-Nieves et al. (1994) and Ogunwande et al. (2005), or other volatiles, repel *D. citri*. Research is also required to determine how guava, other plants that may produce volatiles that repel *D. citri*, or perhaps synthetic repellents, can best be used to reduce the impact of huanglongbing in citrus orchards. There is no evidence to suggest that cajuput volatiles repel *D. citri* adults, but Cen et al. (2008) observed that *D. citri* adults avoid volatiles from Chinese giant hyssop (*Agastache rugosa* (Fisch. & C.A. Mey.) Kuntze [Lamiales: Lamiaceae]). Rather than interplanting, it may be possible to use such plants as groundcovers within orchards (Mike Stewart, Consolidated Citrus, pers. comm., 2007).

As a result of observations on the impact guava on *D. citri* in Việt Nam and China being shared and discussed openly, and with goodwill, at public forums, the University of Florida, Lake Alfred, is reported to have applied for a patent related to 47 compounds identified as guava leaf volatiles (see Rouseff et al. 2008): such is the cost of sharing information freely. Rouseff et al. (2008) also detected seven sulfur volatiles: hydrogen sulfide, sulfur dioxide, methanethiol, dimethyl sulfide (DMS), dimethyl disulfide (DMDS), methional and dimethyl trisulfide. They (Rouseff et al. 2008) noted that DMDS is an insect toxic, defensive volatile produced only by wounded guava but not citrus leaves and, thus, may be the component responsible for the protective effect of guava against the HLB vector. It was formed immediately after crushing leaves, and was the major headspace volatile within 10 min.

Appendix XII. Australian Psylloidea including *Diaphorina tryoni* (Froggatt)

The Australian psylloid fauna comprises 354 described species in 58 genera, representing over 10% of the world fauna (Hollis 2004). Most (93%) of the Australian psylloid fauna occurs in the family Psyllidae (see Table 1), due largely to the massive radiation of the Spondyliaspinae on the Myrtaceae. This will increase when a radiation of similar magnitude, of species of *Acizzia* [Psyllidae: Acizziinae] on species of *Acacia* [Fabales: Mimosaceae], is further studied.

The Psyllidae is represented in Australia by the subfamilies Spondyliaspinae (well-documented, on Myrtaceae), the Acizziinae (poorly-known on Mimosaceae), and the Psyllinae and Diaphorinae, with few, mostly introduced species. The familial/subfamilial classification of the Psylloidea remains poorly resolved, with the Spondyliaspinae often referred as a separate family (Becker-Migdisova 1973, Morgan 1984, White & Hodkinson 1985,). The (morphological) classification of White & Hodkinson (1985) places the Diaphorinae distant to the Spondyliaspinae, Acizzinae and Psyllinae. To date, there is no molecular phylogeny that resolves the higher level systematics of the Psylloidea.

One native species of *Diaphorina*, *Diaphorina tryoni* (Froggatt) has been recorded from Australia (Hollis 2004). It was originally described as *Brachypsylla tryoni* Froggatt, from Brisbane, Queensland, and it only occurs in Queensland. Its larvae are free-living and its host is *Conyza viscidula* DC [Asterales: Asteraceae]. It was placed in the genus *Diaphorina* by Hollis (2004).

Table 1. Subfamily placement of genera within the Australian Psyllidae (after Hollis 2004).

Subfamily	Genus
Acizziinae	<i>Acizzia</i> Heslop-Harrison, 1961
Aphalarinae	<i>Aphalara</i> Forster, 1848 (probable misidentification)
Ciriacreminae	<i>Heteropsylla</i> Crawford, 1914
Diaphorinae	<i>Diaphorina</i> Low, 1880
Psyllinae	<i>Aconopsylla</i> Tuthill & Taylor, 1955
Spondyliaspinae	<i>Agelaeopsylla</i> Taylor, 1990
	<i>Anoeconeossa</i> Taylor, 1987
	<i>Australopsylla</i> Tuthill & Taylor, 1955
	<i>Blastopsylla</i> Taylor, 1985
	<i>Blepharocosta</i> Taylor, 1992
	<i>Boreioglycaspis</i> Moore, 1964
	<i>Cardiaspina</i> Crawford, 1911
	<i>Creiis</i> Scott, 1882
	<i>Cryptoneossa</i> Taylor, 1990
	<i>Ctenarytaina</i> Ferris & Klyver, 1932
	<i>Dasypsylla</i> Froggatt, 1900
	<i>Eriopsylla</i> Froggatt, 1901
	<i>Eucalyptolyma</i> Froggatt, 1901
	<i>Geijerolyma</i> Froggatt, 1903
	<i>Glycaspis</i> Taylor, 1960
	<i>Hyalinaspis</i> Taylor, 1960
	<i>Kenmooreana</i> Taylor, 1984
	<i>Lasiopsylla</i> Froggatt, 1900
	<i>Leptospermonastes</i> Taylor, 1987
	<i>Phellopsylla</i> Taylor, 1960
	<i>Phyllolyma</i> Scott, 1882
	<i>Platyobria</i> Taylor, 1987
	<i>Spondylaspis</i> Signoret, 1879
	<i>Syncarpiolyma</i> Froggatt, 1901
Unplaced	<i>Anomalopsylla</i> Tuthill, 1952

Atmetocranium Tuthill, 1952
Brinckitia Heslop-Harrison, 1961
Cacopsylla Ossiannilsson, 1970
Colophorina Capener, 1973
Epipsylla Kuwayama, 1908
Euryconus Aulmann, 1912
Haplaphalara Uichanco, 1921
Insnesia Tuthill, 1964
Paurocephala Crawford, 1914
Prosopidopsylla Burckhardt, 1987
Psyllopsis Low, 1879
Spondytora Klimaszewski, 1997
Trisetipsylla Yang & Li, 1984

Staff of the Northern Australia Quarantine Strategy (NAQS) have conducted surveys for *D. citri* and HLB on introduced and native *Citrus* species and *Citrus* relatives within the in their ongoing surveillance program over more than 10 years in northern Australia from Cairns on the east coast of Queensland to Broome on in Western Australia. Plants targeted include *Aegle marmelos*, *Bergera koenigii* L., cultivated and native *Citrus*, *Luvunga monophylla* (DC.) Mabb., *Murraya paniculata* (L. Jack), *Mu. paniculata* L. var. *ovatifoliolata* Engl. [Aurantioideae: Aurantieae], *Glycosmis trifoliata* (Blume) Spreng., *Micromelum minutum* (Forster f.) Wight & Arn. [Aurantioideae: Clauseneae], *Melicope elleryana* (F.Muell.) T.G.Hartley and *Zanthoxylum parviflorum* Benth. [Aurantioideae: Rutoideae]. No psyllids have been observed on these plants during these surveys (Shaun Barclay & Barbara Waterhouse, NAQS, pers. comm. with Paul De Barro, CSIRO, 2006). PCR tests reported by Weinert et al. (2004) for plants with visual symptoms resembling symptoms of HLB were all negative.

In surveys conducted by CSIRO in the Northern Territory (28 April to 12 May 2005) and in Queensland (18 October 2005 to 4 January 2006) no psyllids known to feed on species of Rutaceae were found on any of the *Citrus* species, *Citrus* hybrids, or *Citrus* relatives surveyed, nor were any psyllids observed feeding on these plants. Records are summarised in Table 2 and Table 3.

Table 2. Aurantioideae in Queensland surveyed for the presence of psyllids by PJ Hart & B Gray, CSIRO Division of Entomology, in 2005.

<i>Citrus</i> sp. or <i>Citrus</i> relative	Psyllid species	Notes	Locality	GPS coordinates
<i>Citrus australis</i>			powerstation site, Wivenhoe-Somerset Rd., Splyard Ck.	27° 22' 20.9" S 152° 38' 07.9" E
<i>Citrus australis</i>			Simjue Lane, off Wivenhoe-Somerset Rd, Crossdale area.	27° 16' 02.6" S 152° 37' 28.7" E
<i>Citrus garrawayi</i>			Mt White, Coen	13° 57' 41.5" S 143° 11' 20.7" E
<i>Citrus garrawayi</i>			Mt White, Coen	13° 57' 47.9" S 143° 11' 21.9" E
<i>Citrus garrawayi</i>			CSIRO Lab, Atherton	17° 15' 32.6" S 145° 29' 07.3" E
<i>Citrus garrawayi</i>			Coen	13° 57' 21.0" S 143° 11' 33.1" E
<i>Citrus glauca</i>	<i>Hyalinaspis</i> sp.	11 ♂ 7 ♀: lerps on <i>Eucalyptus</i> spp.	Southwood National Park, SW of Moonie	27° 48' 50.3" S 150° 05' 34.2" E
<i>Citrus glauca</i>	<i>Acizsa</i> 'sp. 1'.	1 ♂ 4 ♀: free living on Leguminosae	Southwood National Park, SW of Moonie	28° 48' 50.3" S 150° 05' 34.2" E
<i>Citrus glauca</i>	<i>Blastopsylla</i> sp.	1 ♂: lerps on <i>Eucalyptus</i> spp.	Southwood National Park, SW of Moonie	29° 48' 50.3" S 150° 05' 34.2" E

<i>Citrus glauca</i>			Yarrill Ck. Mt Carmel Rd Nth. of Goondiwindi	28° 10' 00.6" S 150° 26' 59.8" E
<i>Citrus glauca</i>	<i>Acizzia</i> 'sp. 1'	2 ♂ 1 ♀: free living on Leguminosae	Hopeland Rd roadside, E of Chinchilla	26° 50' 07.8" S 150° 40' 40.0" E
<i>Citrus glauca</i>	<i>Acizzia</i> 'sp. 2'	1 ♂: free living on Leguminosae	Hopeland Rd roadside, E of Chinchilla	27° 50' 07.8" S 150° 40' 40.0" E
<i>Citrus glauca</i>			Roma	26° 34' 35.7" S 148° 50' 35.7" E
<i>Citrus glauca</i>			Surat	27° 11' 41.8" S 149° 12' 54.8" E
<i>Citrus glauca</i>			Yarril Creek, Nth of Goondiwindi	28° 10' 00.6" S 150° 27' 03.9" E
<i>Citrus inodora</i>			base of cableway near Bellenden Ker	17° 16' 11.3" S 145° 54' 00.2" E
<i>Citrus × limon</i>			Tansey Rd, Kilkivan	26° 03' 03.8" S 152° 07' 10.1" E
<i>Citrus reticulata</i>			Gayndah	25° 37' 39.1" S 151° 36' 54.6" E
<i>Clausena brevistyla</i> Oliver			Thomas Rd, Atherton	17° 15' 54.6" S 145° 33' 57.8" E
<i>Clausena brevistyla</i>			Bridle Ck, Mareeba	17° 58' 35.6" S 145° 35' 50.8" E
<i>Clausena brevistyla</i>			Carrington Rd, near Atherton	17° 17' 37.8" S 145° 27' 03.8" E
<i>Glycosmis</i> sp.			Thomas Rd, Atherton	19° 15' 54.6" S 145° 33' 57.8" E
<i>Glycosmis trifoliata</i>			Mt Etna Caves Nat. Park, Rockhampton	23° 09' 14.3" S 150° 29' 13.8" E
<i>Glycosmis trifoliata</i>			Wangetti Beach, Qld.	16° 41' 14.2" S 145° 34' 53.4" E
<i>Glycosmis trifoliata</i>			Cairns to Mareeba Rd, Kuranda	16° 36' 34.4" S 145° 31' 47.8" E
<i>Glycosmis trifoliata</i>			Townsville	19° 11' 46.0" S 146° 46' 22.8" E
<i>Glycosmis trifoliata</i>			Cape Cleveland, Sth of Townsville	19° 16' 24.2" S 147° 02' 22.5" E
<i>Micromelum minutum</i>			Norval Park. Nth of Bundaberg	24° 36' 31.9" S 152° 07' 48.3" E
<i>Micromelum minutum</i>			Mt Etna Caves Nat. Park, Rockhampton	23° 09' 12.1" S 150° 27' 36.6" E
<i>Micromelum minutum</i>			Capricorn Coast Nat. Park, Bluff Point	23° 10' 57.1" S 150° 47' 37.5" E
<i>Micromelum minutum</i>			Bridle Ck, Mareeba	16° 58' 43.9" S 145° 36' 00.3" E
<i>Micromelum minutum</i>			Bridle Ck, Mareeba	16° 58' 35.6" S 145° 35' 50.8" E
<i>Micromelum minutum</i>			Townsville	20° 11' 46.0" S 146° 46' 22.8" E
<i>Murraya paniculata</i>			Cania Dam lookout, Nth of Monto	24° 39' 09.2" S 150° 58' 58.2" E
<i>Murraya paniculata</i>			Nambour	26° 36' 44.0" S 152° 58' 14.0" E
<i>Murraya paniculata</i>			Pomonad	26° 20' 42.6" S 152° 51' 11.0" E
<i>Murraya paniculata</i>			Sempfs Rd, Dundowran Beach	25° 16' 40" S

	area, Hervey Bay	152° 44' 50" E
<i>Murraya paniculata</i>	Kirbys Rd, Bundaberg	24° 49' 38.1" S
		152° 23' 10.8" E
<i>Murraya paniculata</i>	Gayndah	25° 37' 39.1" S
		151° 36' 54.6" E
<i>Murraya paniculata</i>	Kingaroy	26° 32' 39.2" S
		151° 50' 17.3" E
<i>Murraya paniculata</i>	31 Hastie Rd, Atherton	17° 17' 13.5" S
		145° 29' 25.9" E
<i>Murraya paniculata</i>	Townsville	19° 19' 28.6" S
		146° 50' 22.1" E
<i>Murraya paniculata</i>	Innisfail	17° 31' 27.5" S
		146° 01' 34.6" E
<i>Murraya paniculata</i>	Pt Douglas	16° 29' 52.3" S
		145° 27' 47.0" E
<i>Murraya paniculata</i>	Cairns	16° 55' 00.0" S
		145° 46' 00.0" E
<i>Murraya paniculata</i> var. <i>ovatifoliolata</i>	Mt Etna Caves Nat. Park, Rockhampton	23° 09' 12.7" S
		150° 27' 38.3" E
<i>Murraya paniculata</i> var. <i>ovatifoliolata</i>	Alton Downs Rd, Rockhampton	23° 11' 23.3" S
		150° 07' 30.8" E
<i>Murraya paniculata</i> var. <i>ovatifoliolata</i>	'Fonthill Stn' Wst of Mt Molloy	16° 40' 47.9" S
		145° 10' 57.7" E
<i>Murraya paniculata</i> var. <i>ovatifoliolata</i>	Mt White, Coen	13° 57' 47.7" S
		143° 11' 21.4" E
<i>Murraya paniculata</i> var. <i>ovatifoliolata</i>	Townsville	19° 11' 46.0" S
		146° 46' 22.8" E

Table 3. Aurantioideae in the Northern Territory surveyed for the presence of psyllids by GS Taylor & G Fichera, CSIRO Division of Entomology, in 2006

<i>Citrus</i> sp. or <i>Citrus</i> relative	Psyllid species	Notes	Locality	GPS coordinates
<i>Aegle marmelos</i>		small white scale	Darwin Botanic Gardens	
<i>Bergera koenigii</i>		juvenile flatid exuviae on leaf sample	Howard Springs Nature Park	12° 27.45' S 131° 03.03' E
<i>Citrus gracilis</i>		cerambycid chewing stem	near Howard Springs, Sayer Road	12° 33.27' S 131° 04.21' E
<i>Citrus gracilis</i>		<i>Siphanta</i> sp. (pale green)	near Berrimah	12° 27.25 S 130° 57.08' E
<i>Citrus gracilis</i>		whitefly	near Berrimah	12° 27.47' S 130° 57.13' E
<i>Citrus gracilis</i>		brown stem scale	Near Berrimah	12° 27.52' S 130° 57.15' E
<i>Citrus gracilis</i>	<i>Acizzia</i> 'sp. 2'.	free living on Leguminosae: observed in spider web	near Berrimah	12° 27.52' S 130° 57.17' E
<i>Citrus gracilis</i>		small white scale	near Howard Springs, Sayer Road	12° 33.25' S 131° 04.19' E
<i>Citrus gracilis</i>		Nematocera	near Howard Springs, Sayer Road	12° 33.27' S 131° 04.19' E
<i>Citrus gracilis</i>		green leaf scale	Near Howard Springs, Sayer Road	12° 33.27' S 131° 04.21' E
<i>Citrus gracilis</i>		orange leaf scale	Near Howard Springs, Sayer Road	12° 33.27' S 131° 04.21' E

<i>Citrus maxima</i>	pink scale	Darwin Botanic GaRoadens	
<i>Citrus</i> sp.	large white coccid	Howard Springs	12° 27.15' S 131° 03.03' E
<i>Citrus</i> sp.	pink scale on home garden tree	Howard Springs Nature Park	12° 27.45' S 131° 03.03' E
<i>Glycosmis macrophylla</i> (Blume) Miq. (syn. <i>Glycosmis sapindoides</i> Oliver)	shiny green leaf chrysomelid	~5 km NW Mt Burrell, Tipperary Stn SE edge of limestone sinkhole	13° 27.90' S 130° 59.95' E
<i>Glycosmis macrophylla</i>	shiny green leaf chrysomelid	~5 km NW Mt Burrell, Tipperary Stn SE edge of limestone sinkhole	13° 27.92' S 130° 59.95' E
<i>Micromelum minutum</i>	small pale cicadellid (species 1)	Cutta Cutta Caves, near entrance	14° 34.75' S 132° 28.17' E
<i>Micromelum minutum</i>	20 spotted coccinellid	Cutta Cutta Caves, near entrance	14° 34.75' S 132° 28.17' E
<i>Micromelum minutum</i>	red scale	Cutta Cutta Caves, S Katherine	14° 34.75' S 132° 28.17' E
<i>Micromelum minutum</i>	white fluffy scale	Cutta Cutta Caves, S Katherine	14° 34.75' S 132° 28.17' E
<i>Micromelum minutum</i>	whitefly	Cutta Cutta Caves, S Katherine	14° 34.77' S 132° 28.17' E
<i>Micromelum minutum</i>	medium brown cicadellid	East Point, near Darwin	
<i>Micromelum minutum</i>	small cicadellid (species 2)	East Point, near Darwin	
<i>Murraya paniculata</i>		Fogg Dam, amenities block	12° 34.12' S 131° 18.45' E
<i>Murraya paniculata</i>		Fogg Dam, amenities block	12° 34.12' S 131° 18.45' E
<i>Murraya paniculata</i>		Fogg Dam, amenities block	12° 34.12' S 131° 18.45' E
<i>Murraya paniculata</i>		Fogg Dam, amenities block	12° 34.12' S 131° 18.45' E
<i>Murraya paniculata</i>		Fogg Dam, amenities block	12° 34.12' S 131° 18.45' E
<i>Murraya paniculata</i>		Fogg Dam, amenities block	12° 34.12' S 131° 18.45' E
<i>Murraya paniculata</i>	small white moth	Finnis River	13° 01.38' S 130° 57.13' E
<i>Murraya paniculata</i>	flatid	Finnis River	13° 01.40' S 130° 57.10' E
<i>Murraya paniculata</i>	small white scale	Cutta Cutta Caves, near entrance	14° 34.73' S 132° 28.17' E
<i>Murraya paniculata</i>	5 spotted coccinellid	Cutta Cutta Caves, near entrance	14° 34.8' S 132° 28.1' E
<i>Murraya paniculata</i>	5 spotted coccinellid	Cutta Cutta Caves, near entrance	14° 34.8' S 132° 28.1' E
<i>Murraya paniculata</i>	small white scale	Cutta Cutta Caves, near entrance	14° 34.8' S 132° 28.1' E
<i>Murraya paniculata</i>	<i>Siphanta</i> sp. on ornamental	Darwin, near Esplanade	

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**SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
REFERENCES COMMITTEE**

Inquiry into the review of the citrus industry in Australia

Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013 and Thursday, 4 July 2013

Department of Agriculture, Forestry and Fisheries (DAFF)

Written Questions on Notice - Senator Ruston

Question 1	Biosecurity	Can DAFF provide information on the following issues regarding biosecurity: 1. Does DAFF have a <u>current</u> contingency plan for exotic citrus pests and diseases across Australia? 2. Does DAFF have a <u>current</u> contingency plan for Huanglongbing (HLB)? 3. How regularly are these contingency plans updated? 4. When was the HLB contingency plan last updated? 5. What resources has DAFF allocated to the risk management and/or contingency plans for exotic pests and diseases, including HLB/Asian citrus psyllid (ACP)? 6. What current resources are there in place to detect HLB and the ACP? 7. What are the estimated costs to contain and eradicate HLB? 8. Has DAFF modelled the potential economic impact of HLB on the Australian citrus industry and allied industries? 9. Has DAFF, in conjunction with the industry, undertaken any communication activities to ensure citrus growers are aware of HLB, are able to identify an incursion, and know how to respond?
Question 2	Biosecurity	During evidence the Chair asked a number of question that DAFF took on notice. Can DAFF provide answers to the following: 1. Where the nearest events of Huanglongbing (HLB) have been detected. 2. Whether there has ever been a detection in Papua New Guinea. 3. Provide a briefing on the HLB contingency plan. 4. What is the plan if HLB "...turns up in the next cyclone"?
Question 3	Levy	Can DAFF advise of the process undertaken by DAFF to determine that Citrus Australia Ltd is the Peak Industry Body (PIB) for the Australian citrus industry? Can DAFF further advise the process by which they determine the ongoing legitimacy of a previously-approved PIB and how regularly this is undertaken?

Question 4	Citrus IAC records	In DAFF's report <i>Investigation of claims of a conflict-of-interest affecting the advice offered to Horticulture Australia Ltd by its Citrus and Avocado Industry Advisory Committees</i> (http://www.daff.gov.au/agriculture-food/hort-policy/investigation-of-claims-of-a-conflict-of-interest-affecting-the-advice-offered-to-horticulture-australia-ltd-by-its-citrus-and-avocado-industry-advisory-committees) it is stated: "HAL also reported poor record-keeping practices by the avocado and citrus IAC secretariats, which impeded HAL's analysis of the IAC's actions and decisions." Can DAFF advise of the actions taken to remedy this situation with respect to the citrus IAC secretariat and whether DAFF is satisfied that this remedial action has been successful? Can DAFF further advise how this remedial action has been measured?
Question 5	Deed of Agreement 2010-14	Can DAFF advise how it satisfies itself that no funds have been paid to the Peak Industry Body (PIB) for the Australian citrus industry, Citrus Australia Ltd, for the purposes of: • agri-political activity; • sitting fees; • salaries and running costs of the PIB other than those directly attributable to consultations with the Horticulture Australia Ltd (HAL) and the PIB constituency on matters which it is progressing with HAL; or • capital expenditure. Can DAFF also provide evidence that it has governance arrangements in place that are sufficiently transparent to enable DAFF to be assured that Citrus Australia Ltd is not using any HAL-allocated funds for the above listed purposes?
Question 6	Deed of Agreement 2010-14	Section 7 of the Deed of Agreement 2010-14 between the Commonwealth of Australia and Horticulture Australia Ltd (HAL) states: <i>7.2 HAL shall apply the funds during a particular period only in the manner that is consistent with:</i> <i>(a) the HAL Strategic Plan;</i> <i>(b) the HAL Annual Operational Plan; and</i> <i>(c) the Guidelines</i> <i>and must apply the funds in a manner that is efficient, effective and ethical.</i> Can DAFF advise if it is satisfied that above requirements are being met? Further, Section 6 of the Deed (Management of Funds) states: <i>6.1 HAL must establish such accounting systems as are necessary to ensure:</i> <i>(c) an auditor is able to readily verify that the funds have been used only in accordance with this deed.</i> Can DAFF advise if they are satisfied that the above requirements have been met?

Question 7	Deed of Agreement 2010-14	Section 11 (Strategic and Annual Operational Plans) of the Deed of Agreement 2010-14 between the Commonwealth of Australia and Horticulture Australia Ltd (HAL) states: <i>11.3 In developing the strategic plan HAL must:</i> <i>(a) ensure that there is effective consultation with levy payers and that their priorities are reflected in the strategic plan.</i> In this regard could DAFF advise the following: • Does DAFF have access to the names and contact details of citrus levy payers? • Does DAFF or HAL have the capacity/mechanism to build/create a database of citrus levy payers? • Does DAFF or HAL communicate directly with citrus levy payers to advise them of the consultation process? • How does DAFF or HAL capture levy payers' feedback with respect to research and other levy funded priorities? • If this communication function is delegated to another body, for example Citrus Australia Ltd, how does DAFF or HAL satisfy themselves that this function is been adequately undertaken, particularly given that Citrus Australia Ltd's membership, by its own admission, is less than 13% of levy payers?
Question 8	FOI	Is Horticulture Australia Ltd subject to Freedom of Information requirements with regard to the expenditure of levy funds? If not, why not?
Question 9	Levies Revenue Service	Can DAFF advise total levies collected from the citrus industry by the Levies Revenues Service (LRS) for the years 2009-10, 2010-11, 2011-12 and 2012-13? Can DAFF further advise total administration costs incurred by the LRS in the collection and distribution of citrus industry levies in the years 2009-10, 2010-11, 2011-12 and 2012-13?
Question 10	Export Efficiency Powers	In evidence (p47, Mildura 4 July 2013) DAFF stated: "A review was undertaken and it was found that it would be more beneficial for the industry if we started to move away from having single importing into the US and allowing multiple importers to broaden our presence in the United States." Can DAFF advise at whose instigation this review was undertaken, who undertook this review, and did the review process identify any issues with the establishment of the 'citrus to the USA' marketing program with particular reference to price setting?

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 1

Division/Agency: Plant

Topic: Biosecurity (Citrus greening contingency plan)

Proof Hansard page: Written

Senator RUSTON asked:

Can DAFF provide information on the following issues regarding biosecurity:

1. Does DAFF have a current contingency plan for exotic citrus pests and diseases across Australia?
2. Does DAFF have a current contingency plan for Huanglongbing (HLB)?
3. How regularly are these contingency plans updated?
4. When was the HLB contingency plan last updated?
5. What resources has DAFF allocated to the risk management and/or contingency plans for exotic pests and diseases, including HLB/Asian citrus psyllid (ACP)?
6. What current resources are there in place to detect HLB and the ACP?
7. What are the estimated costs to contain and eradicate HLB?
8. Has DAFF modelled the potential economic impact of HLB on the Australian citrus industry and allied industries?
9. Has DAFF, in conjunction with the industry, undertaken any communication activities to ensure citrus growers are aware of HLB, are able to identify an incursion, and know how to respond?

Answer:

1. Yes. PLANTPLAN, the Australian Emergency Plant Pest Response Plan, is the current preparedness and response guidelines for any incursion of an exotic pest or disease that would affect a plant industry. PLANTPLAN was developed by Plant Health Australia, a non-profit company that is a tripartite partnership between the Commonwealth Government, state and territory governments, and potentially affected plant industries.

2. The department has a copy of the current contingency plan for citrus greening and its vectors. The contingency plan was developed by Professor GAC Beattie and Patricia Barkley through a citrus levy project funded by Horticulture Australia Limited with matching funding from the Commonwealth Government.

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 1 (continued)

3. Contingency plans are updated on an 'as-needed' basis. The contingency plan for citrus greening and its vectors was first developed in 2007, and finalised at a workshop convened by the Commonwealth Government in February 2009.

4. The latest version of the contingency plan for citrus greening and its vectors is dated 10 February 2009.

5. The department provides resources to monitor the presence and movement of citrus greening, citrus psyllids and other high priority pests in the Asia-Pacific region, through the North Australia Quarantine Strategy, the International Plant Health Program, and the Technical Capacity Building Program. The department also provides scientific analysis and advice to ensure import policies are reviewed in response to relevant changes in scientific understanding, and provides inspection services at the Australian border to verify that import conditions are being met.

The department also provides staff to assist in the process of developing industry biosecurity plans through Plant Health Australia, including technical input, operational experience and market analysis.

6. The most effective resource in detecting any pest incursion is growers and crop monitors that regularly inspect crops and are best placed to detect any new or unusual disease symptoms. In addition, the Commonwealth Government undertakes targeted surveys through the Northern Australia Quarantine Strategy and International Plant Health Program for high priority pests that have the potential to spread to Australia through natural means.

7. The costs to contain and eradicate citrus greening disease would depend on the nature and location of any incursion.

8. Information on the potential impacts of Huanglongbing, if it were to establish in Australia, are provided in the *Pest risk analysis report for 'Candidatus Liberibacter species' and their vectors associated with Rutaceae* which can be found at http://www.daff.gov.au/ba/reviews/final-plant/candidatus_liberibacter_and_their_vectors.

9. Awareness of Huanglongbing is provided through pest alerts, data sheets and other information on this disease and its vectors. This information is publically available on the Citrus Australia Limited website and the Plant Health Australia website. This information advertises the Exotic Plant Pest Hotline, the most effective mechanism for suspect or unusual symptoms or plant pests to be reported.

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 1 (continued)

Reports to the hotline are directed to the relevant state or territory agency who have the responsibility to investigate the report and notify the Commonwealth Government if there is a confirmed, or reasonably held suspicion, that the detection is of an exotic plant pest.

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 2

Division/Agency: Plant

Topic: Biosecurity (Huanglongbing)

Proof Hansard page: Written

Senator RUSTON asked:

During evidence the Chair asked a number of question that DAFF took on notice. Can DAFF provide answers to the following:

1. Where the nearest events of Huanglongbing (HLB) have been detected.
2. Whether there has ever been a detection in Papua New Guinea.
3. Provide a briefing on the HLB contingency plan.
4. What is the plan if HLB "...turns up in the next cyclone"?

Answer:

1. Huanglongbing has been detected in Indonesia, Malaysia, Timor-Leste, and Papua New Guinea.

2. Yes.

3. A contingency plan specific to Huanglongbing and its vectors was developed by Professor GAC Beattie and Patricia Barkley through a citrus levy project funded by Horticulture Australia Limited with matching funding from the Commonwealth Government. This contingency plan was finalised at a February 2009 workshop convened by the Commonwealth Government. The contingency plan provides information that would assist with implementation of PLANTPLAN, in the event of an incursion of the pathogens that cause Huanglongbing ('*Candidatus Liberibacter asiaticus*', '*Candidatus Liberibacter africanus*', and '*Candidatus Liberibacter americanus*') and their vectors, the Asian citrus psyllid (*Diaphorina citri*) and the African citrus psyllid (*Trioza erytreae*).

The contingency plan captures relevant technical information on the pathogens, vectors, and host plants and supports industry awareness activities, as well as identifying, delimiting and managing any incursion with a goal of eradication.

4. Any suspected incursion of an exotic plant pest or pathogen would be subject to the response activities and processes detailed in the Emergency Plant Pest Response Deed and PLANTPLAN. In the case of Huanglongbing and its insect vectors, the pest specific contingency plan provides operational details and diagnostic protocols directly relevant to these pests.

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 3

Division/Agency: Agricultural Productivity

Topic: Levy (Peak industry body for the citrus industry)

Proof Hansard page: Written

Senator RUSTON asked: Can DAFF advise of the process undertaken by DAFF to determine that Citrus Australia Ltd is the Peak Industry Body (PIB) for the Australian citrus industry? Can DAFF further advise the process by which they determine the ongoing legitimacy of a previously-approved PIB and how regularly this is undertaken?

Answer:

Horticulture Australia Limited (HAL) must consult with a relevant eligible industry body regarding a levy or charge proposal it submits to the Australian Government.

The Australian Citrus Growers Inc. (ACG) was the eligible industry body under the *Primary Industries Excise Levies Regulations 1999* and the *Primary Industries (Customs) Charges Regulations 2000* for the statutory citrus levies and charges collected by the Australian Government and paid to HAL as the industry service provider.

On 23 October 2008 the ACG wrote to the then Minister for Agriculture, Fisheries and Forestry advising that the ACG was being wound-up with effect on 31 October 2008 and requesting that Citrus Australia Limited (CAL) be recognised as the citrus PIB, particularly in relation to the national statutory citrus levies and charges, from 1 November 2008.

At the time, CAL was the only national representative body that claimed to be relevant to the citrus industry, and more than 75% of ACG's grower members voted for CAL as the new citrus industry representative body to replace ACG, following a three-year consultation program.

In 2009 DAFF asked HAL to confirm all the horticultural eligible industry bodies prescribed in the *Primary Industries (Excise) Levies Regulations 1999* and the *Primary Industries (Customs) Charges Regulations 2000*. HAL confirmed CAL as the appropriate eligible industry body for citrus.

DAFF subsequently ensured that the ACG's replacement by CAL was reflected in the Regulations.

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 3 (continued)

There is no set process for regular review by which DAFF determines the legitimacy of a previously-approved peak industry body. Other bodies may write to the government seeking recognition, either to replace or complement the existing peak industry body.

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 4

Division/Agency: Agricultural Productivity

Topic: Citrus IAC records

Proof Hansard page: Written

Senator RUSTON asked:

In DAFF's report *Investigation of claims of a conflict-of-interest affecting the advice offered to Horticulture Australia Ltd by its Citrus and Avocado Industry Advisory Committees* (www.daff.gov.au/agriculture-food/hort-policy/investigation-of-claims-of-a-conflict-of-interest-affecting-the-advice-offered-to-horticulture-australia-ltd-by-its-citrus-and-avocado-industry-advisory-committees) it is stated: "HAL also reported poor record-keeping practices by the avocado and citrus IAC secretariats, which impeded HAL's analysis of the IAC's actions and decisions." Can DAFF advise of the actions taken to remedy this situation with respect to the citrus IAC secretariat and whether DAFF is satisfied that this remedial action has been successful? Can DAFF further advise how this remedial action has been measured?

Answer:

Horticulture Australia Limited (HAL) appointed an independent governance officer to the citrus Industry Advisory Committee (IAC) to strengthen the IAC's administrative and governance arrangements. This officer assists the IAC Chair and secretariat with governance, improve risk management and manage the implementation of procurement guidelines. The officer reports directly to HAL's Company Secretary.

HAL is appointing independent governance officers to all of its IACs.

DAFF considers it is too soon to evaluate the success of the independent governance officer in improving the administration and governance of the citrus IAC but is monitoring the arrangement through the six-monthly meetings with HAL that are required under the Deed of Agreement 2010-14 between the Commonwealth of Australia and HAL.

DAFF and HAL are discussing the establishment of indicators to measure the effectiveness of governance reforms being implemented by HAL. Appropriate indicators have not yet been agreed.

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 5

Division/Agency: Agricultural Productivity

Topic: Deed of Agreement 2010-14 (Governance arrangements)

Proof Hansard page: Written

Senator RUSTON asked:

Can DAFF advise how it satisfies itself that no funds have been paid to the Peak Industry Body (PIB) for the Australian citrus industry, Citrus Australia Ltd, for the purposes of:

- agri-political activity;
- sitting fees;
- salaries and running costs of the PIB other than those directly attributable to consultations with the Horticulture Australia Ltd (HAL) and the PIB constituency on matters which it is progressing with HAL; or
- capital expenditure.

Can DAFF also provide evidence that it has governance arrangements in place that are sufficiently transparent to enable DAFF to be assured that Citrus Australia Ltd is not using any HAL-allocated funds for the above listed purposes?

Answer:

Horticulture Australia Limited (HAL) must provide to DAFF a Certification Report for the financial year signed by the Chair and the Chief Executive Officer, certifying that HAL has complied with its obligations under the Deed of Agreement 2010-14 between the Commonwealth of Australia and HAL (the Deed) and the *Horticulture Marketing and Research and Development Services Act 2000* (the Act) for the period and that there was no material non-compliance with the Deed or the Act during the period. This includes that no HAL funds were used for agri-political purposes or sitting fees.

Further, under Clause 25 [Assignment and Novation] HAL must ensure that in the case of novation, the assignee agrees to be bound by all of HAL's obligations under the deed.

Under clause 10 [Access to records and use of information], the Commonwealth, the Auditor-General any duly authorised representative of either of them, for the purposes of monitoring compliance by HAL with the Deed, have access to records, premises, can examine and copy HAL's accounts.

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 5 (continued)

It is possible for peak industry bodies (PIBs) undertaking HAL funded projects to use project funds for salaries or other overhead costs or to purchase capital items related to that project as specified in the contract.

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 6

Division/Agency: Agricultural Productivity

Topic: Deed of Agreement 2010-14 (HAL compliance)

Proof Hansard page: Written

Senator RUSTON asked:

Section 7 of the Deed of Agreement 2010-14 between the Commonwealth of Australia and Horticulture Australia Ltd (HAL) states:

7.2 HAL shall apply the funds during a particular period only in the manner that is consistent with:

- (a) the HAL Strategic Plan;*
- (b) the HAL Annual Operational Plan; and*
- (c) the Guidelines*

and must apply the funds in a manner that is efficient, effective and ethical.

Can DAFF advise if it is satisfied that above requirements are being met?

Further, Section 6 of the Deed (Management of Funds) states:

6.1 HAL must establish such accounting systems as are necessary to ensure:

- (a) an auditor is able to readily verify that the funds have been used only in accordance with this deed.*

Can DAFF advise if they are satisfied that the above requirements have been met?

Answer:

DAFF is satisfied that Horticulture Australia Limited (HAL) is meeting the requirements of Section 6 [Management of funds] and Section 7 [Application of funds] of the Deed of Agreement between the Commonwealth of Australia and HAL (the Deed).

As required by Section 16 [Compliance audit report and certification report] of the Deed, HAL has presented DAFF with a Compliance Audit Report for 2011-12. The auditor expressed the opinion that HAL has complied in all material respects, with clauses 6 and 7 of the Deed for the period 1 July 2011 to 30 June 2012.

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 6 (continued)

Pursuant to Clause 16.2 of the Deed, the auditor expressed no opinion on compliance with Clause 7.7 of the Deed in respect to agri-political activity, or with the provisions of Clause 7.2 of the Deed concerning the efficient, effective and ethical application of funds.

As required by Clause 16.3 of the Deed, HAL has presented DAFF with a Certification Report, signed by the Chair and the Chief Executive Officer, for the period 1 July 2011 to 30 June 2012, certifying that HAL has complied with its obligations under the Deed and the Act for the period including that there was no material non-compliance.

On the basis of HAL's current Compliance Audit Report, together with HAL's Certification Report, DAFF is satisfied that HAL is meeting its obligations under Section 6 and 7 of the Deed.

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 7

Division/Agency: Agricultural Productivity

Topic: Deed of Agreement 2010-14

Proof Hansard page: Written

Senator RUSTON asked:

Section 11 (Strategic and Annual Operational Plans) of the Deed of Agreement 2010-14 between the Commonwealth of Australia and Horticulture Australia Ltd (HAL) states:

11.3 In developing the strategic plan HAL must:

(a) ensure that there is effective consultation with levy payers and that their priorities are reflected in the strategic plan.

In this regard could DAFF advise the following:

1. Does DAFF have access to the names and contact details of citrus levy payers?
2. Does DAFF or HAL have the capacity/mechanism to build/create a database of citrus levy payers?
3. Does DAFF or HAL communicate directly with citrus levy payers to advise them of the consultation process?
4. How does DAFF or HAL capture levy payers' feedback with respect to research and other levy funded priorities?

If this communication function is delegated to another body, for example Citrus Australia Ltd, how does DAFF or HAL satisfy themselves that this function is been adequately undertaken, particularly given that Citrus Australia Ltd's membership, by its own admission, is less than 13% of levy payers?

Answer:

DAFF does not have access to the names and contact details of producers who are liable for citrus levy (citrus levy payers). This is because the levy is most often collected at the first point of sale or processing (from intermediaries), and not directly from the producers. To reduce the amount of administrative work required from intermediaries, and to make levy collection as cost-effective as possible, levy legislation does not require that intermediaries provide details of producers from whom they recover levy.

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 7 (continued)

As DAFF does not have the information about who is liable to pay citrus levy it cannot build/create a database of citrus levy payers. Horticulture Australia Limited (HAL) has advised that it may have the capacity to build a database of citrus levy payers were this to be included as a priority in the citrus industry strategic research and development (R&D) investment plan.

Neither DAFF nor HAL communicates directly with citrus levy payers to advise them of the consultation process to support the development of the industry's strategic plan or to capture feedback on R&D priorities. HAL funds its peak industry body (PIB) members to establish and implement communication and consultation programs for this purpose.

HAL funds its PIB members to undertake communication and consultation projects that engage with industry levy payers. HAL's project contracts specify the milestone communication and consultation outcomes required to be delivered by PIBs and provide the mechanism to ensure that the outcomes specified in the contract are delivered. HAL requires PIBs to consult or communicate with all levy payers in the industry, not just those levy payers who are members of the PIB.

The PIB for the Australian citrus industry, Citrus Australia Limited (CAL), developed the industry's 2012-2017 strategic R&D investment plan. According to CAL's 2011-12 Annual Report the communication and consultation process conducted to inform the development of the strategic R&D investment plan included 11 regional stakeholder forums, a national workshop, articles for magazines and newsletters, website updates and a media campaign. The Annual Report states that more than 270 growers were directly consulted in the development of the plan.

HAL does not consult directly with levy payers as part of the process to develop its strategic plans. HAL's strategic plans are drawn from the individual strategic and annual investment plans of HAL's member industries, which are in turn developed on the basis of direct levy payer input.

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 8

Division/Agency: Agricultural Productivity

Topic: FOI

Proof Hansard page: Written

Senator Ruston asked:

Is Horticulture Australia Ltd subject to Freedom of Information requirements with regard to the expenditure of levy funds? If not, why not?

Answer:

No. Horticulture Australia Limited is an incorporated company and the *Freedom of Information Act 1982* expressly excludes incorporated companies.

Rural and Regional Affairs and Transport Committee
Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 9

Division/Agency: Finance and Business Support

Topic: Levies Revenue Service (Citrus levy)

Proof Hansard page: Written

Senator RUSTON asked:

Can DAFF advise total levies collected from the citrus industry by the Levies Revenues Service (LRS) for the years 2009-10, 2010-11, 2011-12 and 2012-13?

Can DAFF further advise total administration costs incurred by the LRS in the collection and distribution of citrus industry levies in the years 2009-10, 2010-11, 2011-12 and 2012-13?

Answer:

The total levies collected and total administration costs incurred by DAFF for citrus levy in the 2009-10, 2010-11 and 2011-12, financial years is shown below. The table also provides the year to date (YTD) citrus levy collections and the estimate of cost recovery charges for the 2012-13 financial year. The final citrus levy return for the 2012-13 financial year is due, with payment, on 28 July 2013.

Financial Year	Total Levy Collected and Disbursed	Cost Recovery Charges
2009-2010	\$1 738 106	\$108 821
2010-2011	\$1 355 653	\$128 901
2011-2012	\$1 727 743	\$128 896
2012-2013	\$1 833 262 (YTD)	\$95 101(Estimate)

Rural and Regional Affairs and Transport Committee

Inquiry into the review of the citrus industry in Australia
Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013
and Thursday, 4 July 2013

Agriculture, Fisheries and Forestry

Question: 10

Division/Agency: Agricultural Productivity

Topic: Export Efficiency Powers

Proof Hansard page: Written

Senator Ruston asked:

In evidence (p47, Mildura 4 July 2013) DAFF stated: “A review was undertaken and it was found that it would be more beneficial for the industry if we started to move away from having single importing into the US and allowing multiple importers to broaden our presence in the United States.” Can DAFF advise at whose instigation this review was undertaken, who undertook this review, and did the review process identify any issues with the establishment of the ‘citrus to the USA’ marketing program with particular reference to price setting?

Answer:

The export efficiency powers review was a requirement of the 2010-14 Deed of Agreement between the Commonwealth of Australia and Horticulture Australia Limited (HAL).

To guide the review, the Department of Agriculture, Fisheries and Forestry (DAFF) convened an inter-departmental committee of officials representing DAFF, the Department of Finance and Deregulation, Department of Foreign Affairs and Trade and Department of Industry, Innovation, Science, Research and Tertiary Education. The Chairman and secretariat for the review was provided by DAFF.

To inform the review, between October 2011 and August 2012 the Australian Bureau of Resource and Agricultural Economics and Sciences prepared an independent report analysing the current export regulations against the principles of National Competition Policy.

No, the review did not identify any issues with the establishment by HAL of the ‘citrus to the USA’ marketing program.

**SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
REFERENCES COMMITTEE**

Inquiry into the review of the citrus industry in Australia

Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013 and Thursday, 4 July 2013

Food Standards Australia and New Zealand (FSANZ)

Written Questions on Notice - Senator Ruston

Question 1	Carbendazim	Can FSANZ advise: • what was the process or action that preceded the decision for the recommendation to remove the maximum residue level (MRL) for carbendazim in imported frozen concentrated orange juice; • which organisations or bodies provided submissions, or lobbied, both in support and against the removal of the MRL; • what was FSANZ's recommendation to the Australian Government regarding the removal of this MRL; and • which agency was responsible for the reinstatement of the MRL.

SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
REFERENCES COMMITTEE

Inquiry into the review of the citrus industry in Australia

Public Hearings held 3 and 4 July 2013

Food Standards Australia New Zealand (FSANZ)
Responses to Written Questions on Notice - Senator Ruston

1. What was the process or action that preceded the decision for the recommendation to remove the maximum residue level (MRL) for carbendazim in imported frozen concentrated orange juice?

FSANZ has not at any time recommended removal of an MRL for carbendazim specifically for imported concentrated orange juice. FSANZ develops standards, including MRL standards, for all food sold in Australia, whether imported or produced domestically.

The question might be directed to a proposal that was made, in November 2011, by the Australian Pesticides and Veterinary Medicines Authority (APVMA) to amend the relevant food standard to remove MRLs for carbendazim for some foods. The APVMA has had a limited statutory power to amend the MRL Standard in the Food Standards Code (if it is considering an application or variation in relation to a chemical product and considers that it is likely that an amendment of the MRL in the Food Standards Code will be required) since 1 March 2011.

On 8 November 2011 the APVMA sought public comment on its proposal to amend Schedule 1 of Standard 1.4.2 of the Food Standards Code to remove some maximum residue limits for carbendazim, including the maximum residue limit for citrus fruits, and to include a maximum residue limit for onions. The APVMA proposal followed a review by the APVMA of the use of carbendazim. The APVMA had previously varied the relevant MRLs in the APVMA's MRL Standard.

In early 2012, the fruit juice industry advised FSANZ that removal of the MRL in the Food Standards Code for carbendazim for citrus fruits could adversely affect the importation of frozen concentrated orange juice to Australia and threaten supply of orange juice and orange juice products to the domestic market.

Given the limitation on APVMA's statutory powers when amending the Food Standards Code, including a limitation on its power to consider trade issues or the desirability of an efficient and internationally competitive food industry (matters that FSANZ is required to consider), FSANZ and the APVMA agreed that the APVMA would discontinue its proposal to amend the Food Standards Code and that FSANZ would prepare a proposal to consider the variations.

2. Which organisations or bodies provided submissions, or lobbied, both in support and against the removal of the MRL?

Citrus juice industry representatives met with FSANZ to discuss their concerns regarding the APVMA proposal to remove the carbendazim maximum residue limit for citrus fruits. The Australian Beverages Council wrote to FSANZ on the issue and provided a technical report (attached). FSANZ subsequently assessed the information provided as part of Proposal M1008.

3. What was FSANZ's recommendation to the Australian Government regarding the removal of this MRL?

FSANZ made no recommendation to the Australian Government. The Australian Government does not determine MRLs.

During 2012 FSANZ developed a draft variation of the Code that included certain MRLs for carbendazim (Proposal M1008). The draft variation was, in accordance with procedures established in the *Food Standards Australia New Zealand Act 1991*, sent to the Council of Australian Governments Legislative and Governance Forum on Food Regulation convening as the Australia and New Zealand Food Regulation Ministerial Council (Forum) on 6 November 2012. FSANZ was advised on 3 January 2013 that the Forum had agreed not to seek a review in relation to Proposal M1008 and, accordingly, the variation was gazetted on 18 January 2013.

The effect of the variation in relation to most citrus fruits was to reduce the MRL from 10 milligrams per kilogram of food to 0.2 milligrams per kilogram of food. A copy of the approval report for Proposal M1008 is attached.

4. Which agency was responsible for the reinstatement of the MRL?

No agency was responsible for reinstatement of the carbendazim MRL. The MRL for carbendazim was not varied between May 2006 and the variation referred to in Answer 3 in January 2013, except for the inclusion of a MRL for carbendazim in garlic in September 2011.

10 February 2012



Food Standards Australia and New Zealand
PO Box 7186
CANBERRA ACT 2610

Dear Janis,

CARBENDAZIM IN ORANGE JUICE

I refer to our previous meeting and subsequent correspondence regarding the issue of carbendazim (CBZ) in orange juice and the proposed revocation of the existing permissions within the Food Standards Code (FSC) for CBZ for citrus as well as a range of other fruits and vegetables.

Fruit Juice Australia (FJA), a division of the Australian Beverages Council, would like acknowledge FSANZ's willingness to engage with the Australian fruit juice industry to resolve what could have been a catastrophic event should the original gazettal for the revocation of the various MRLs had of gone through as planned. The assistance and understanding of the Australian Pesticides and Veterinary Medicines Authority is also acknowledged.

Following the meeting in Canberra on 24 January 2012, you requested the industry supply FSANZ with a range of information that was outlined in an e-mail from you dated 25 January and a subsequent e-mail dated 3 February 2012 that would assist FSANZ in:

1. the consideration of developing a revised CBZ MRL for citrus and
2. gauging what impact the revocation of the CBZ MRLs for other fruits and vegetables would have on the industry.

To that end, the industry submits the following Technical Submission that it is hoped will assist FSANZ in both of these regards.

Given the relatively short but necessary timeframe within which the industry has had to meet in submitting the information, it is noted that additional data is needed for some aspects of point two above and may be needed as FSANZ considers both the revised CBZ MRL for citrus and the impact of the revocation for other fruits and vegetables. The industry offers whatever assistance is necessary to supply any additional data or evidence.

The industry again appreciates FSANZ's willingness to work with it to resolve the issues at hand, and looks forward to progressing towards a mutually agreeable outcome that encompasses both safe food and a viable and sustainable juice industry.

Yours sincerely,

Geoff Parker
Chief Executive Officer



Carbendazim (CBZ) in Orange Juice

Technical Submission

Submitted by

Fruit Juice Australia

a division of the Australian Beverages Council Ltd

10 February 2012

Contact:

Geoff Parker - Chief Executive Officer

Fruit Juice Australia

Introduction

The Australian Beverages Council is the peak industry body representing the \$7bn non-alcoholic refreshment beverages industry. Members collectively produce over 95% of the market's production volume and represent small, medium and large companies involved in the manufacture and distribution of a broad range of beverages including carbonated diet and regular soft drinks, energy drinks, sports and isotonic drinks, formulated beverages, bottled and packaged waters, fruit juice and fruit drinks, cordials, iced tea and ready to drink coffee.

Fruit Juice Australia (FJA), a division of the Australian Beverages Council, is dedicated to representing the unique interests of the nation's juice manufacturers and represents over 90% of the juice market's production volume. Members produce a wide range of juice products including 100% fruit juice and juice drinks. A list of FJA members is found in Appendix One.

In January 2012, the FJA became aware of the pending revocation of the current permissions within the Food Standards Code (FSC) for the fungicide carbendazim (CBZ) across a range of fruits and vegetables. This proposed change followed a lengthy review by the Australian Pesticides and Veterinary Medicines Authority (APVMA) on CBZ and followed suspension of its use in domestic agricultural applications.

This submission is made on behalf of FJA and is comprised of the collective information of all the members of the association. This submission will assist in providing Food Standards Australia and New Zealand (FSANZ) with a range of industry information, namely:

1. Identify what products are still in the market that were produced prior to the 2010 suspension of CBZ use domestically
2. Outline a range of key industry and market data for fruit juice in Australia
3. Provide information and evidence on current CBZ levels to assist with the development a new maximum residue limit (MRL) for CBZ for citrus
4. Alert FSANZ to the significant impact that the revocation of the current MRLs for other fruits/vegetables will have on the industry and consumers.

Industry Information

1. Stock produced prior to January 2010

Following investigation, the two market leaders - Lion and HJ Heinz, advised to the FJA that the companies were confident that there are no products available for sale within the supply chain containing domestically produced oranges treated with CBZ prior to January 2010.

Additional research with other FJA members confirmed the unlikelihood that product pre-January 2010 would still be available for sale within the market.

2. Key Industry & Market Data

Consumption

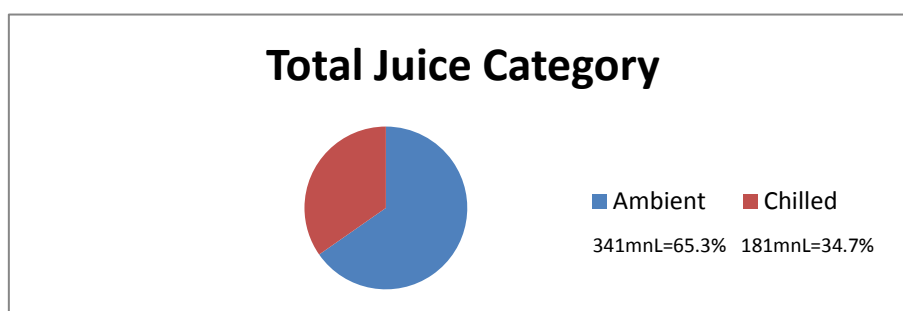
- Australian households consume approximately 50L of juice annually
- Total juice production (consumption) equates to approximately 522,000,000 million litres pa
- Total consumption equals 23L per capita per annum on average
- Australian children consume on average 122mL of juice daily

Juice categories

The juice market is divided into ambient and chilled categories.

Ambient juice refers to its ability to maintain quality at ambient temperatures and all products in this category can be found on the supermarket shelves. These will all be blends of local and imported juice. This portion of the total juice market represents approximately 341 million litres or 65.3%.

Chilled juice can be found in the supermarket chilled section and is less stable than ambient hence its need for refrigeration. These products will either be 100% local content or a blend of local and imported product. Chilled juice represents approximately 181 million litres or 34.7% of the total market.



Source: Directus/ABARE

Sources of juice

Each year, the Australian juice industry has an underlying demand of approximately 500,000 metric tonnes (MT) of fruit. Valencia is the preferred orange for juicing as it is generally sweeter and is not as bitter as navel oranges. The domestic citrus growing industry can only supply approximately 250,000 MT of valencia crop, allowing for seasonal variability. One MT of oranges produces on average approximately 500 litres of juice.

This disparity results in a year on year shortfall in crop supply of approximately 250,000 MT of oranges which results in shortfall of approximately 125,000,000 litres of juice to domestic manufacturers.

To cover this annual shortfall, Frozen Concentrate Orange Juice (FCOJ) is being imported into Australia from a range of countries (see Table One) that all comply with the current FSC MRL for CBZ of 10mg/kg in the reconstituted single strength juice. The juice industry has been sourcing FCOJ from a range of countries since the 1970s.

Table One – FCOJ Origin Markets

Country Of Origin	December 2011 MT	YTD MT	2010 MT
Argentina		187.04	16.09
Belgium	37.80	651.00	264.6
Belize		18.90	
Brazil	3330.19	26517.51	28940.89
China			37.8
Chile			13.24
Costa Rica		528.56	400.5
Cuba		36.17	
Indonesia		0.63	17.16
Israel	74.13	593.53	425.31
Italy	19.20	196.61	192.76
Mexico	23.40	387.38	82.26
Netherlands	57.95	608.70	66.95
New Zealand		2.04	
Philippines			
Portugal			37.8
Singapore		55.65	
South Africa		7.50	
Turkey		8.01	
United Kingdom			3.51
United States of America	180.48	2605.62	1916.9
Uruguay	19.74	75.39	
Grand Total	3742.89	32480.24	32282.71

Source: Directus/ABARE

As is evident from the data in Table One, for 2010 the Australian juice industry sourced 28,940 MT of FCOJ from Brazil, representing 89.6% of the total FCOJ imports for that year. The dominance of Brazilian FCOJ in the supply chain is reflected in the quantity of FCOJ sourced from that market by the two market leaders.

Lion currently source 85% of their FCOJ from Brazil, and the remaining 15% from Australia. The majority of the FCOJ is used for ambient juice production which accounts to approximately 45% of the total Lion Dairy & Drinks Juice business.

Heinz currently sources 95% of their FCOJ from Brazil, the remaining 5% from Australia. Approximately 27% of all Heinz (Golden Circle) Juice products contain imported FCOJ.

Reconstituting factor

FCOJ that is imported is then reconstituted back to single strength juice. FCOJ has a Brix value of 66 (66°B). Typically single strength juice has a Brix of 10 (10°B).

The ratio of FCOJ being reconstituted back to single strength juice is:

- One MT of FCOJ @ 66°B = 6,358 litres of single strength @ 10°B.

Where:

- Specific gravity of FCOJ is 1.32516.
- Dilution factor is approximately 8.4

3. Current CBZ levels

As CBZ is not a regularly tested chemical in incoming FCOJ imports, limited data is available at this time. Data from Lion and Heinz and their respective suppliers has been sourced as well as limited test results from samples taken recently.

Test results from Lion

The information given by the suppliers of FCOJ indicates that the levels over the last five years falls in the range of ND (<0.005) – 0.014 mg/litre on reconstituted juice.

As advised previously, it is industry practice for all FCOJ in Australia to be reconstituted to 10°B.

Testing carried out recently on stock in Australia bears this out with a reading of 0.007mg/litre on the reconstituted juice.

The average of all samples tested both from supplier reports and producers is 0.009 mg/litre on reconstituted juice.

More testing is currently being undertaken on a full range of imported fruit juice concentrates, pastes and purees with a view to more accurately assessing the quantities in the foodstuffs.

Test results from Heinz

Heinz sampled 15 concentrate samples, for which the results are found in the following table:

Format	Range (mg/kg)	No of Samples	Average Results (mg/kg)
Concentrate	ND- 0.094	n=15	0.06
Theoretical(single strength)	N/a	N/a	0.007
Actual	N/a	N=2	ND-0.006

Industry recommended MRL

In proposing a recommended MRL, and understanding the work FSANZ will undertake regarding dietary exposure, the industry has given due consideration to earlier advice from FSANZ that any MRL above 1.9ppm would not be acceptable. Further consideration was given to what other standards setting agencies and jurisdictions had developed as a MRL for CBZ. These include:

- Current NZFSA MRL of 5mg/kg
- Current Codex MRL of 1mg/kg
- Current EU MRL of 0.2mg/kg
- Current USA MRL of 0.01mg/kg (level of detection)
- Current NHMRC health value in drinking water of 0.09mg/L.

The industry respectfully recommends a MRL of 0.5mg/kg as being a workable limit for CBZ for citrus fruits which would apply to FCOJ and single strength juice.

4. Impact of CBZ MRL revocation for other fruits/vegetables

An extensive survey of members was undertaken following a request from FSANZ as to whether any industry impact would be experienced should the other CBZ MRLs for a range of fruits and vegetables other than citrus were also to be revoked under the planned gazettal.

Industry can advise FSANZ that in many circumstances the impact would be significant and in some instances eg apple (40,000 MT), as significant as for citrus. The industry is still gathering data but initial indications are that virtually all of the fruits and vegetables either flagged as having their MRLs revoked or moving to temporary status with possible future revocation are all imported into Australia in various forms and quantities. The estimated total import quantity is approximately 48,000 MT.

Table Two below outlines top line data for these other fruits and vegetables. Additional data is being sourced for those fruits/vegetables with 'TBA' fields and will be provided to FSANZ as it comes to hand. It should be noted that these imports in the proceeding table are for the juice industry's use only and does not include any other sectors' requirements eg retail supermarkets, allied industries etc.

Table Two - Current Fruit/Vegetable Imports

Fruit	Juice Format		Fruit	Country of origin	Approx annual import volume	CBZ used		MRL
	Frozen	Aseptic	IQF			Yes	No	
Grape		68 brix concentrate		Argentina Chile Spain Italy	1,300mt	TBA	TBA	
Mango		28 brix puree conc and S/S puree		Mexico Ecuador Peru Brazil India	1,800mt	TBA	TBA	
Banana		S/S puree	Yes	Ecuador Costa Rica	1,000mt	TBA	TBA	
Blackcurrant	65 Brix Concentrate	65 Brix Concentrate	Yes	New Zealand Poland Austria Germany	400mt	European	NZ	< 10ppb (Europe)
Strawberry	65 Brix Concentrate & S/S puree	65 Brix Concentrate & S/S puree	Yes	Germany Poland	60mt	Yes		< 10ppb
Raspberry	65 Brix Concentrate & S/S puree	65 Brix Concentrate & S/S puree	Yes	Germany Serbia	30mt	Yes		< 10ppb
Elderberry	65 Brix Concentrate & S/S puree	65 Brix Concentrate		Germany	20mt	Yes		< 10ppb
Blackberry	65 Brix Concentrate & S/S puree	65 Brix Concentrate	Yes	Germany	20mt	Yes		< 10ppb
Boysenberry	65 brix Concentrate		Yes	New Zealand	20mt		No	
Cranberry	50 Brix Concentrate & S/S Puree		Yes	USA	400mt		No	
Apricot		32 Brix Paste		China	400mt	Yes		0.5ppm
Peach	TBA	TBA			TBA	TBA	TBA	
Nectarine	TBA	TBA			TBA	TBA	TBA	
Cherry	65 Brix Concentrate	65 Brix Concentrate		Germany	10mt	Yes		< 10ppb
Apple	70 Brix Concentrate 55 Brix Concentrate	70 Brix Concentrate		New Zealand China 82% Poland	40,000mt		NZ	Ch 2ppm NZ 3ppm
Pear	70 Brix Concentrate	70 Brix Concentrate		New Zealand China Poland	1,500mt		NZ	
Tomato		32 Brix Paste		China	400mt	Yes		0.5ppm
Carrot	42 Brix Concentrate			New Zealand	100mt		No	
Red Beet	68 Brix Concentrate			Europe	5mt		No	
Prune		70 brix concentrate		Chile Argentina	500mt		TBA	

Appendix One – FJA Members

Bevco

CB Juice

Coca-Cola South Pacific

Directus

Emma and Tom

Fruitmark

Grove Fruit Juices

HJ Heinz Australia

International Flavors and Fragrances

Juicy Isle

Just Squeezed

Lion

Mildura Fruit Juices

Mountain Fresh Juices

Nippy's

Nudie

Schweppes Australia

The Product Makers

Tradexaisa

Interaustfoods

Visy

Vitality Brands

8 November 2012
[26-12]

Approval Report – Proposal M1008

Maximum Residue Limits (2012)

Food Standards Australia New Zealand (FSANZ) has assessed a proposal prepared by FSANZ to amend maximum residue limits for a number of agricultural and veterinary chemicals.

On 17 July 2012, FSANZ sought submissions on draft MRL variations and published an associated report. FSANZ received twelve submissions.

FSANZ approved the draft variations on 31 October 2012. The COAG Legislative and Governance Forum on Food Regulation¹ (Forum) was notified of FSANZ's decision on 6 November 2012.

This Report is provided pursuant to paragraph 63(1)(b) of the *Food Standards Australia New Zealand Act 1991* (the FSANZ Act).

¹ Previously known as the Australia and New Zealand Food Regulation Ministerial Council

Table of Contents

1. EXECUTIVE SUMMARY	2
2. INTRODUCTION	3
2.1 THE PROPOSAL.....	3
2.2 THE CURRENT STANDARD	3
2.3 REASONS FOR PREPARING THE PROPOSAL.....	3
2.4 PROCEDURE FOR ASSESSMENT	4
2.5 DECISION	4
3. SUMMARY OF THE FINDINGS	4
3.1 RISK ASSESSMENT	4
3.2 RISK MANAGEMENT.....	5
3.2.1 <i>Summary of submissions</i>	5
3.3 RISK COMMUNICATION	7
3.3.1 <i>World Trade Organization</i>	7
3.3.2 <i>Codex Alimentarius Commission Standards</i>	8
3.3.3 <i>Impacts on imported foods of MRL variations proposed by the APVMA</i>	10
4. REASONS FOR DECISION	11
4.1 ADDRESSING FSANZ'S OBJECTIVES FOR STANDARDS-SETTING	13
4.1.1 <i>Protection of public health and safety</i>	13
4.1.2 <i>The provision of adequate information relating to food to enable consumers to make informed choices</i>	13
4.1.3 <i>The prevention of misleading or deceptive conduct</i>	13
4.1.4 <i>Subsection 18(2) considerations</i>	13
4.3 IMPLEMENTATION.....	14
ATTACHMENT A – APPROVED VARIATIONS TO THE AUSTRALIA NEW ZEALAND FOOD STANDARDS CODE.....	15
ATTACHMENT B – EXPLANATORY STATEMENT.....	22
ATTACHMENT C – MRLS PROPOSED IN RELATION TO MRL HARMONISATION REQUESTS	24
ATTACHMENT D – DIETARY EXPOSURE ESTIMATES	26

1. Executive summary

The purpose of this Proposal was to consider incorporating certain maximum residue limits (MRLs) for agricultural and veterinary chemicals that may legitimately occur in food in Standard 1.4.2 in the *Australia New Zealand Food Standards Code* (the Code).

Standard 1.4.2 lists the MRLs for agricultural and veterinary chemical residues which may occur in foods in Australia. Limits prescribed in the Code constitute a mandatory requirement applying to all food products of a particular class whether produced domestically or imported.

The Proposal includes consideration of MRLs gazetted by the Australian Pesticides and Veterinary Medicines Authority (APVMA) in November 2011 for carbendazim and dimethoate, and MRLs requested by other parties to further align the Code with Codex or trading partner standards.

The risk assessment indicates that the proposed limits for the agricultural and veterinary chemical residues of interest do not present any public health and safety concerns for dietary exposure to the chemical residues in relation to relevant health-based guidance values. The Proposal does not include consideration of any MRLs for antibiotic residues in food.

Inclusion of the MRLs in the Code will permit the sale of foods containing legitimate residues and protect public health and safety by minimising residues in foods consistent with the effective control of pests and diseases.

The *Agreement between the Government of Australia and the Government of New Zealand concerning a Joint Food Standards System* (the Treaty) excludes MRLs for agricultural and veterinary chemicals in food from the system setting joint food standards.

FSANZ made a Sanitary and Phytosanitary notification to the World Trade Organization (WTO). The Government of the Argentine Republic provided comments. FSANZ has addressed the issues raised in section 3 of this Report.

2. Introduction

2.1 The Proposal

The Proposal was prepared to consider varying certain MRLs in the Code. This is a routine process, both to include limits to allow the sale of food with legitimate residues and to remove limits that the Australian Pesticides and Veterinary Medicines Authority (APVMA) has already removed from the APVMA MRL Standard. The Proposal includes consideration of MRL variations proposed by the APVMA, as well as MRL harmonisation requests from other interested parties.

2.2 The current Standard

Standard 1.4.2 lists the limits for agricultural and veterinary chemical residues which may occur in foods. Limits prescribed in the Code constitute a mandatory requirement applying to all food products of a particular class whether produced domestically or imported. Food products with residues exceeding the relevant limit listed in the Code cannot legally be supplied in Australia. This ensures that residues of agricultural and veterinary chemicals are kept as low as possible and consistent with the approved use of chemical products to control pests and diseases of plants and animals.

2.3 Reasons for preparing the Proposal

The purpose of this Proposal is to vary MRLs for residues of agricultural or veterinary chemicals in food, see **Attachments A, B**.

The Proposal includes consideration of MRL variations for carbendazim and dimethoate proposed by the APVMA in Gazette No. APVMA 22, Tuesday, 8 November 2011². These MRL variations relate to regulatory decisions on the use of chemical products made by the APVMA as part of its reviews of carbendazim and dimethoate. FSANZ and the APVMA agreed that the APVMA would discontinue its proposal to amend carbendazim and dimethoate MRLs in the Code and that FSANZ would consult further with interested parties and raise a proposal to consider these variations.

The Proposal also includes consideration of MRLs to further align the Code with Codex and trading partner standards, including some additional carbendazim and dimethoate MRLs. These MRLs were requested by the Australian Beverages Council, BASF, Bryant Christie, the California Citrus Quality Council, the California Grape and Tree Fruit League, the California Table Grapes Commission, the Cranberry Marketing Committee, DeGroot Technical Services Pty Limited, Langdon Ingredients, Max Mark International (Australia) Pty Limited, Monsanto, the Northwest Horticultural Council and Syngenta.

Internationally, countries set MRLs according to good agricultural practice (GAP) or good veterinary practice (GVP). Agricultural and veterinary chemicals are used differently in different countries around the world as pests, diseases and environmental factors differ and because product use patterns may differ. This means that residues in imported foods may legitimately differ from those in domestically produced foods.

The proposed MRLs will permit the sale of foods containing legitimate residues and protect public health and safety by minimising residues in foods consistent with the effective control of pests and diseases.

² http://www.apvma.gov.au/publications/gazette/2011/22/gazette_2011-11-08_page_38.pdf

The limits may minimise potential trade disruption and extend consumer choice. MRLs proposed in relation to requests to harmonise limits in the Code with trading partner or Codex limits are listed at **Attachment C**.

2.4 Procedure for assessment

The Proposal was assessed under the General Procedure.

2.5 Decision

The draft variations as proposed following assessment were approved without change.

The draft variations are at **Attachment A**.

3. Summary of the findings

3.1 Risk assessment

To assess the public health and safety implications of chemical residues in food, FSANZ estimates the dietary exposure to chemical residues from potentially treated foods in the diet and compares the dietary exposure with the relevant health-based guidance value, for example, the acceptable daily intake (ADI)³ or the acute reference dose (ARfD)⁴.

The ADI and ARfD for individual agricultural and veterinary chemicals are established by the Office of Chemical Safety (OCS) following an assessment of the toxicology of each chemical. In the case that an Australian ADI or ARfD has not been established, a Joint Food and Agriculture Organization / World Health Organization Meeting on Pesticide Residues (JMPR) ADI or ARfD may be used for risk assessment purposes.

FSANZ conducts and reviews dietary exposure assessments using the best available scientific data and internationally recognised risk assessment methodology. Variations to limits in the Code will not be supported where estimated dietary exposures to the residues of a chemical indicate a potential public health and safety risk for the population or a population sub group.

The steps undertaken in conducting each risk assessment were:

- determining the residues of a chemical in a treated food
- estimating dietary exposure to a chemical from relevant foods, using residue data and food consumption data from national nutrition surveys
- completing a risk characterisation where estimated dietary exposures were compared to the relevant health-based guidance value.

FSANZ has reviewed the dietary exposure assessments submitted by the APVMA and conducted additional dietary exposure assessments as part of the assessment of the limits requested by other parties.

³ The ADI is the amount of chemical that may be consumed every day for an entire lifetime without causing an appreciable risk to health.

⁴ The ARfD is an estimate of the maximum amount of a substance in food or drinking water, expressed as milligrams per kilogram of body-weight, that can be ingested in one meal or one day, without appreciable health risk to the consumer, on the basis of all the known facts at the time of the evaluation.

The approved MRLs do not present any public health and safety concerns. The dietary exposure estimates are at **Attachment D**.

3.2 Risk management

FSANZ is committed to maintaining limits in the Code that reflect residues that may legally occur in food; this ensures that such food may be sold. The safety of the residues in the context of the Australian diet is a key consideration. FSANZ will only approve variations to limits in the Code where the risk assessment concludes that estimated dietary exposure is within health-based guidance values. FSANZ may consider including MRLs in the Code that are harmonised with those established by a trading partner in certain circumstances, including that the residues are likely to occur in food available in Australia, do not present safety concerns and are associated with the controlled use of chemical products in the country where the food is produced.

3.2.1 Summary of submissions

Consultation is a key part of FSANZ's standards development process. FSANZ acknowledges the time taken by individuals and organisations to make submissions.

Every submission on an application or proposal is reviewed by FSANZ staff, who examine the issues identified and prepare a response to those issues. While not all comments can be taken on board during the process, they are valued and all contribute to the rigour of our assessment.

FSANZ sought public comment to assist in finalising the assessment of the proposed MRL changes outlined in the Call for Submissions document. Comments were invited on any impacts (costs/benefits) of the proposed variations, in particular, likely impacts on importation of food if specific variations are advanced and any public health and safety considerations associated with the proposed changes.

Comments from one World Trade Organization (WTO) member and twelve submissions were received. The submissions are available at <http://www.foodstandards.gov.au/foodstandards/proposals/proposalm1008maximum5465.cfm>.

Table 1: Summary of issues raised in submissions

Issue	Raised by	FSANZ Response (including any amendments to drafting)
MRL harmonisation request on the basis of potential trade impact on cherry imports if the proposed reduction of the carbendazim/cherries MRL is approved	The California Cherry Marketing and Research Board	Unfortunately there was insufficient time to complete the assessment of this issue within the timeframe for this project. This issue will be considered further and an alternative MRL may be proposed in MRL Proposal M1009. FSANZ is liaising with the California Cherry Marketing and Research Board in this regard.

Issue	Raised by	FSANZ Response (including any amendments to drafting)
Safety of residues in food where increased or additional MRLs are proposed	Private individual	FSANZ's decision in relation to approving MRL variations is based on ensuring that there are no health and safety concerns and that the sale of legally treated food is permitted. FSANZ uses the best available scientific data and methodology in its assessments. MRLs are not direct public health limits and are set at levels well below those that would cause an adverse health effect. Further information: Chemicals in food
Adoption of Codex MRLs as a matter of principle	Dairy Australia Australian Pork Limited	FSANZ notes that consideration of policy issues cannot be made as part of an MRL proposal for varying particular MRLs. The current approach allows FSANZ to consider specific residue limits for inclusion in the Code, such as Codex or other requested MRLs where appropriate. FSANZ assessed several MRLs requested by interested parties in this Proposal. FSANZ considers that this is an efficient approach to assessing the safety and legitimacy of limits for potential residues in imported foods. FSANZ remains committed to ensuring that practical and flexible mechanisms exist to consider standards for residues in food and encourages interested parties to continue to engage with us on residues issues.
Information request	The Government of the Argentine Republic The NSW Food Authority	FSANZ provided the requested information.
Supports progression of the Proposal	The Australian Beverages Council Australian Food and Grocery Council Food and Beverage Importers Association Food Technology Association of Australia Northwest Horticultural Council The United States Cranberry Marketing Committee Victorian Department of Health jointly with Dairy Food Safety Australia	FSANZ values the expertise and engagement of interested parties.

Issue	Raised by	FSANZ Response (including any amendments to drafting)
MRL harmonisation requests for chemical/food combinations not considered in this Proposal	The United States Cranberry Marketing Committee (CMC)	FSANZ notes that Australia is an important market for USA cranberries and that harmonised standards reduce the potential for trade disruption. FSANZ may consider the CMC requests for consideration of certain MRLs for cranberries in future. FSANZ is liaising with the CMC in this regard.

3.3 Risk communication

FSANZ adopted a basic communication strategy for this Proposal, with a focus on alerting the community that changes to the Code are being contemplated.

FSANZ called for public comment on the proposed changes to the Code to help finalise the assessment. Comments were invited on, but not limited to, any impacts (costs/benefits) of the proposed variations, in particular, likely impacts on importation of food if specific variations are advanced and any public health and safety considerations associated with the proposed changes.

FSANZ publishes details about proposed changes, submissions and subsequent reports on its website, alerts more than 5000 subscribers via email about the availability of these reports for comment, and issues a Notification Circular and media releases drawing attention to proposed Code amendments.

Social media and FSANZ publications are also used to communicate calls for submissions.

Individuals and organisations making submissions on this Proposal are notified at each stage of the assessment. FSANZ will notify any gazetted changes to the Code in the national press and on the FSANZ website.

3.3.1 World Trade Organization

As a member of the WTO, Australia is obligated to notify WTO member nations where proposed mandatory regulatory measures are inconsistent with any existing or imminent international standards and where the proposed measure may have a significant effect on trade.

Limits prescribed in the Code constitute a mandatory requirement applying to all food products of a particular class whether produced domestically or imported. Food products with residues exceeding the relevant limit listed in the Code cannot legally be supplied in Australia.

This Proposal included consideration of varying limits in the Code for residues of agricultural and veterinary chemicals in food that are addressed in the international Codex standard. Limits in the Proposal relate to chemical residues that may occur in heavily traded agricultural commodities that may indirectly have a significant effect on trade of derivative food products between WTO members.

The primary objective of the measure is to support the regulation of the use of agricultural and veterinary chemical products to protect human, animal and plant health and the environment. Therefore, a notification to the WTO under Australia's obligations under the WTO Sanitary and Phytosanitary Measures Agreement (SPS Agreement) was made to enable other WTO members to comment on the proposed amendments.

The Government of the Argentine Republic requested information on the proposed carbendazim MRL for grapes. FSANZ provided this information.

3.3.2 Codex Alimentarius Commission Standards

Codex standards are used as the relevant international standard to determine whether a new or changed standard requires a WTO notification.

FSANZ may consider varying limits for residues of agricultural or veterinary chemicals in food in a Proposal where interested parties have identified anomalies between the Code and international standards that may result in adverse impacts. FSANZ must have regard to its WTO obligations, the promotion of consistency between domestic and international food standards and the promotion of fair trading in food. These matters encompass a consideration of international standards and trade issues. The assessment gives careful consideration to public health and safety. In some cases the Australian MRL may exceed a Codex MRL due to different use patterns from those considered at the time the Codex MRL was set. In these cases, as for the consideration of any MRL, the assessment process ensures that the levels of residues in food are safe.

Interested parties provided information that specific anomalies between the Code and Codex or other standards may present barriers to trade in certain foods. The approved variations to the Code would align limits in the Code with international standards and/or standards in producer or other importing countries and permit the sale in Australia of relevant foods containing legitimate residues that do not present health or safety concerns.

As a starting point to assist interested parties in identifying possible impacts, FSANZ compiled a table of proposed MRLs with corresponding Codex limits and sought comment on any ramifications. The following table lists limits approved in this Proposal where there is a corresponding Codex limit. Note that numerical MRL values may not be directly comparable as residue definitions may differ.

Chemical Food	Approved limit ^{††} mg/kg	Codex limit mg/kg
Abamectin Citrus fruits	0.02	0.01
Azoxystrobin Citrus fruits	10	15

Chemical Food	Approved limit ^{†‡} mg/kg	Codex limit mg/kg
Carbendazim		
Apple	0.2	Pome fruits 3
Apricot	2	2
Banana	T1	0.2
Berries and other small fruits [except grapes]	T5	1
Cherries	0.5	10
Ginger, root	T10	Root or rhizome 0.1
Grapes	0.3	3
Nectarine	0.2	2
Oranges	0.2	Oranges, Sweet, Sour (including Orange-like hybrids): several cultivars 1
Peach	0.2	2
Pear	0.2	Pome fruits 3
Tomato	0.5	0.5
Chlorantraniliprole		
Cranberry	1	Berries and other small fruits 1
Clothianidin		
Cranberry	0.01	Berries and other small fruits [except grapes] 0.07
Cyfluthrin		
Citrus fruits	0.2	0.3
Cypermethrin		
Stone fruits	1	2
Cyprodinil		
Stone fruits	2	2
Difenoconazole		
Dried grapes	6	Grapes 0.1
Grapes	4	
Dimethoate		
Artichoke, globe	T1	0.05
Asparagus	0.02	*0.05
Cabbages, head	T0.2	Cabbage, savoy *0.05
Cauliflower	T0.3	0.2
Celery	T0.5	0.5
Cereal Grains	T0.5	Barley 2
Cherries	T0.2	Wheat 0.05
Citrus fruits	5	2
Edible offal (mammalian)	0.1	5
Fruit [except as otherwise listed under this chemical]	Omit 5	Cattle, Edible offal of *0.05
Galangal, rhizomes	Omit T2	Sheep, Edible offal of *0.05
Legume vegetables	T2	Olives 0.5
Peppers, Chili	T5	Pear 1
Peppers, Sweet	0.7	Roots or rhizomes *0.1
Potato	0.1	Peas (pods and succulent=immature seeds) 1
Turner, root	Omit T2	Peppers Chili, dried 3
Turnip, garden	*0.2	Peppers, Sweet (including pimento or pimienta) 0.5
Vegetables [except as otherwise listed under this chemical]	Omit 2	0.05
Wheat bran, processed	T1	Roots or rhizomes *0.1
Fenpyroximate		
Citrus fruits	0.6	0.1
		Brussels sprouts 0.2
		Lettuce, Head 0.3
		Sugar beet 0.05
		Turnip greens 1
		Wheat 0.05

Chemical Food	Approved limit ^{†‡} mg/kg	Codex limit mg/kg
Glyphosate		
Maize	5	5
Rape seed (canola)	20	Rape seed 20
Indoxacarb		
Stone fruits	2	1
Mandipropamid		
Grapes	2	2
Phosmet		
Blueberries	10	10
Lemon	5	Citrus fruits 3
Mandarins	5	
Pyrimethanil		
Citrus fruit [except lemon]	10	Citrus fruits 7
Lemon	11	
Spinetoram		
Citrus fruits	3	Oranges, Sweet, Sour (including Orange-like hybrids): several cultivars 0.07
Spirodiclofen		
Citrus fruits	0.5	0.4
Stone fruits	1	2

[†] Note that a 'T' indicates that the limit is temporary.

[‡] An asterisk indicates that the limit is at or about the limit of analytical quantification.

3.3.3 Impacts on imported foods of MRL variations proposed by the APVMA

Deletions or reductions of MRLs may affect imported foods containing residues that currently comply with existing MRLs. In cases where deletions are proposed by the APVMA, these existing MRLs are no longer required for domestically produced food. FSANZ is committed to ensuring that the implications of MRL variations are considered. Under the current process for considering variations to the Code, FSANZ encourages submissions including information demonstrating a need for an alternative specific MRL variation to be considered rather than the proposed variation. FSANZ will consider amending proposed MRL variations to continue to allow the sale of food where such MRLs are supported by adequate data or information demonstrating that the residues are legitimate and likely to occur. The risk assessment will consider dietary exposure in the context of the Australian diet. Further information on data requirements may be obtained from FSANZ.

To assist in identifying possible impacts on imported foods, FSANZ compiled the following table of foods where MRLs were proposed for deletion or reduction and sought comment on any ramifications for imported foods.

Chemical
Food
Carbendazim Avocado Cereal grains Citrus fruits Custard apple Fruiting vegetables, cucurbits Fruiting vegetables, other than cucurbits [except mushrooms] Grapes Herbs Litchi Mango Papaya (pawpaw) Peanut Pistachio nut Pome fruits Stone fruits Turmeric root Other vegetables [except garlic and pulses]
Dimethoate Avocado Chervil Fruiting vegetables, cucurbits Galangal, rhizomes Herbs Litchi Lupin (dry) Mizuna Peach Peppers, Sweet Quandong Rucola (rocket) Strawberry Tomato Turmeric, root Other fruit [except abiu, banana passionfruit, bearberry, bilberries, blackberries, blueberries, cactus fruit, citrus fruits, cranberry, raspberries, rollinia, santols, mango, watermelon and other assorted tropical and sub-tropical fruits – inedible peel] Other vegetables [except legume vegetables, chilli peppers and melons]

4. Reasons for decision

FSANZ had regard to the matters under section 59 of the FSANZ Act. These are: -

- whether costs that would arise from a food regulatory measure developed or varied as a result of the Proposal outweigh the direct and indirect benefits to the community, Government or industry that would arise from the development or variation of the food regulatory measure

A Regulation Impact Statement was not required because the variations to Standard 1.4.2 are minor and do not substantially alter existing arrangements.

The MRL variations benefit Australian Government, state and territory agencies, growers and producers, in that they serve to further harmonise agricultural and food standards. Achieving further consistency between agricultural and food legislation will minimise compliance costs to primary producers and assist in efficient enforcement of regulations.

Importers may benefit or be disadvantaged by the approval of the variations. Additional or increased MRLs may benefit importers and consequently, consumers in that this may extend the options to source safe foods.

Any MRL deletions or reductions have the potential to restrict importation of foods and could potentially result in higher food prices and a reduced product range available to consumers. However, if a need is identified through consultation, there is scope under current processes to retain specific MRLs where the residues do not present a human health risk, and there is a legitimate Codex or trading partner MRL.

FSANZ considers on balance that the direct and indirect benefits likely to arise from the variation are likely to outweigh the costs likely to arise from the variation.

- whether other measures (whether available to FSANZ or not) would be more cost-effective than a food regulatory measure developed or varied as a result of the Proposal

There were no measures that could achieve the same result other than an amendment to Standard 1.4.2.

- any relevant New Zealand standards

The Agreement between the Government of Australia and the Government of New Zealand concerning a Joint Food Standards System (the Treaty) excludes MRLs for agricultural and veterinary chemicals in food from the system setting joint food standards. Australia and New Zealand independently and separately develop MRLs for agricultural and veterinary chemicals in food.

All domestically produced food sold in New Zealand must comply with the New Zealand (Maximum Residue Limits of Agricultural Compounds) Food Standards 2011 and any amendments (the New Zealand MRL Standards). If food is imported into New Zealand, such food must comply either with the New Zealand MRL Standards or with Codex MRLs (except for food imported from Australia). Food imported from Australia that complies with Standard 1.4.2 can be legally sold in New Zealand.

Under the New Zealand MRL Standards, agricultural chemical residues in food must comply with the specific MRLs listed in the Standards. The New Zealand MRL Standards also include a provision for residues of up to 0.1 mg/kg for agricultural chemical / commodity combinations not specifically listed.

Further information about the New Zealand MRL Standards is available on the New Zealand Ministry for Primary Industries website:

<http://www.foodsafety.govt.nz/industry/sectors/plant-products/pesticide-mrl/>

Limits in the Code and in the New Zealand MRL Standards may differ for a number of legitimate reasons including differing use patterns for chemical products as a result of varying pest and disease pressures and varying climatic conditions.

- any other relevant matters.

There were no other relevant matters.

4.1 Addressing FSANZ's objectives for standards-setting

FSANZ has considered the three objectives in subsection 18(1) of the FSANZ Act during the assessment of this Proposal as follows.

4.1.1 Protection of public health and safety

FSANZ has reviewed the dietary exposure assessments submitted by the APVMA and conducted additional dietary exposure assessments to assess the MRLs requested by other parties. Using the best available scientific data and internationally recognised risk assessment methodology, FSANZ concluded that in relation to current health-based guidance values, the approved MRLs do not present any public health and safety concerns.

4.1.2 The provision of adequate information relating to food to enable consumers to make informed choices

This objective is not relevant to matters under consideration in the Proposal.

4.1.3 The prevention of misleading or deceptive conduct

This objective is not relevant to matters under consideration in the Proposal.

4.1.4 Subsection 18(2) considerations

FSANZ has also had regard to the matters set out in subsection 18(2). These are:

- the need for standards to be based on risk analysis using the best available scientific evidence

FSANZ's primary role in developing food regulatory measures for residues of agricultural and veterinary chemicals in food is to ensure that estimated exposures to potential residues are within health-based guidance values. As described in Section 4.1.1, FSANZ conducts and reviews risk assessments using the best available scientific data and internationally recognised risk assessment methodology.

- the promotion of consistency between domestic and international food standards

The changes would remove inconsistencies between agricultural and food standards; and further align the Code with Codex and trading partner standards.

- the desirability of an efficient and internationally competitive food industry

The MRL variations ensure openness and transparency in relation to the residues that could reasonably occur in food. The changes will minimise potential costs to primary producers, rural and regional communities and importers in terms of permitting the sale of food containing legitimate residues.

- the promotion of fair trading in food

Section 4 lists a number of considerations that address fair trading with respect to MRL variations in this proposal.

- any written policy guidelines formulated by the Ministerial Council⁵.

FSANZ has had regard to the Ministerial Council Policy Guideline on the Regulation of Residues of Agricultural and Veterinary Chemicals in Food, in particular the specific policy principles to be consistent with the effective regulation of the registration, permission and use of agricultural and veterinary chemicals; promote a consistent approach to MRLs for both domestic and imported foods, where appropriate; and be consistent with Australia's obligations under the WTO SPS Agreement.

4.3 Implementation

The amendments will take effect on gazettal.

Attachments

- A. Approved variations to the *Australia New Zealand Food Standards Code*
- B. Explanatory Statement
- C. MRLs approved in relation to MRL harmonisation requests
- D. Dietary exposure estimates

⁵ Now known as the COAG Legislative and Governance Forum on Food Regulation.

Attachment A – Approved variations to the *Australia New Zealand Food Standards Code*



Food Standards (Proposal M1008 – Maximum Residue Limits (2012)) Variation

The Board of Food Standards Australia New Zealand gives notice of the making of this variation under section 92 of the *Food Standards Australia New Zealand Act 1991*. The Standard commences on the date specified in clause 3 of this variation.

Dated X

Standards Management Officer
Delegate of the Board of Food Standards Australia New Zealand

1 Name

This instrument is the *Food Standards (Proposal M1008 – Maximum Residue Limits (2012)) Variation*.

2 Variation to Standards in the *Australia New Zealand Food Standards Code*

The Schedule varies the Standards in the *Australia New Zealand Food Standards Code*.

3 Commencement

These variations commence **on the date of gazettal**.

SCHEDULE

[1] Standard 1.4.2 is varied by

[1.1] inserting in alphabetical order in Schedule 1 the food and associated MRLs for each of the following chemicals

“

Acequinocyl Sum of acequinocyl and its metabolite 2-dodecyl-3-hydroxy-1,4-naphthoquinone, expressed as acequinocyl	
Citrus fruits	0.2
Dicamba Sum of dicamba, 3,6-dichloro-5-hydroxy-2-methoxybenzoic acid and 3,6-dichloro-2-hydroxybenzoic acid, expressed as dicamba	
Soya bean (immature seeds)	10
Fluoxastrobin Sum of fluoxastrobin and its Z isomer	
Cranberry	1.9
Fluxapyroxad Fluxapyroxad	
Plums (including prunes)	3
Pome fruits	0.8
Pulses [except soya bean (dry)]	0.4
Soya bean (dry)	0.3
Soya bean (immature seeds)	0.15
Stone fruits [except plums (including prunes)]	2
Spirodiclofen Spirodiclofen	
Citrus fruits	0.5
Stone fruits	1
Spiromesifen Sum of spiromesifen and 4-hydroxy-3-(2,4,6-trimethylphenyl)-1-oxaspiro[4.4]non-3-en-2-one, expressed as spiromesifen	
Cranberry	2

”

[1.2] omitting from Schedule 1 the foods and associated MRLs for each of the following chemicals

“

Carbendazim	
Sum of carbendazim and 2-aminobenzimidazole, expressed as carbendazim	
Avocado	3
Cereal grains	*0.05
Citrus fruits	10
Custard apple	1
Fruiting vegetables, cucurbits [except as otherwise listed under this chemical]	2
Fruiting vegetables, other than cucurbits [except mushrooms]	2
Herbs	T3
Litchi	10
Mango	5
Melons, except watermelon	4
Papaya (pawpaw)	T20
Peanut	0.2
Pistachio nut	T0.1
Pome fruits	5
Stone fruits	10
Turmeric root	T3
Vegetables [except as otherwise listed under this chemical]	3
Cypermethrin	
Cypermethrin, sum of isomers	
Stone fruits [except cherries]	1
Dimethoate	
Sum of dimethoate and omethoate, expressed as dimethoate see also Omethoate	
Chervil	T2
Fruit [except as otherwise listed under this chemical]	5
Fruiting vegetables, cucurbits	5
Galangal, rhizomes	T2
Herbs	T2
Litchi	5
Lupin (dry)	0.5
Mizuna	T2
Peach	3
Quandong	T5
Rucola (rocket)	T2
Turmeric, root	T2
Vegetables [except as otherwise listed under this chemical]	2
Glyphosate	
Sum of glyphosate and Aminomethylphosphonic acid (AMPA) metabolite, expressed as glyphosate	
Cereal grains [except as otherwise listed under this chemical]	T*0.1
Indoxacarb	
Sum of indoxacarb and its <i>R</i> -isomer	
Cherries	T2
Stone fruits [except cherries]	2
Pyrimethanil	
Pyrimethanil	
Citrus fruits	7

”

[1.3] inserting in alphabetical order in Schedule 1 the foods and associated MRLs for each of the

following chemicals

“

Acetamiprid	
<i>Commodities of plant origin:</i> Acetamiprid	
<i>Commodities of animal origin:</i> Sum of acetamiprid and N-demethyl acetamiprid ((E)-N ¹ -[(6-chloro-3-pyridyl)methyl]-N ² -cyanoacetamidine), expressed as acetamiprid	
Citrus fruits	0.5
Cranberry	0.6
Bifenazate	
Sum of bifenazate and bifenazate diazene (diazenecarboxylic acid, 2-(4-methoxy-[1,1'-biphenyl-3-yl] 1-methylethyl ester), expressed as bifenazate	
Cranberry	1.5
Carbendazim	
Sum of carbendazim and 2-aminobenzimidazole, expressed as carbendazim	
Apple	0.2
Apricot	2
Cherries	0.5
Citron	0.7
Grapefruit	0.2
Lemon	0.7
Lime	0.7
Mandarins	0.7
Mineola	0.7
Nectarine	0.2
Onion, bulb	T*0.2
Oranges	0.2
Peach	0.2
Pear	0.2
Shaddock (pomelo)	0.2
Tangelo [except mineola]	0.2
Tangors	0.7
Tomato	0.5
Chlorantraniliprole	
<i>Plant commodities and animal commodities other than milk:</i> Chlorantraniliprole	
<i>Milk:</i> Sum of chlorantraniliprole, 3-bromo-N-[4-chloro-2-(hydroxymethyl)-6-[(methylamino)carbonyl]phenyl]-1-(3-chloro-2-pyridinyl)-1H-pyrazole-5-carboxamide, and 3-bromo-N-[4-chloro-2-(hydroxymethyl)-6-[[[(hydroxymethyl)amino]carbonyl]phenyl]-1-(3-chloro-2-pyridinyl)-1H-pyrazole-5-carboxamide, expressed as chlorantraniliprole	
Cranberry	1
Clothianidin	
Clothianidin	
Cranberry	0.01
Cyfluthrin	
Cyfluthrin, sum of isomers	
Citrus fruits	0.2
Stone fruits	0.3
Cypermethrin	
Cypermethrin, sum of isomers	
Stone fruits	1

Difenoconazole Difenoconazole	
Dried grapes	6
Grapes	4
Dimethoate Sum of dimethoate and omethoate, expressed as dimethoate <i>see also</i> Omethoate	
Abiu	5
Artichoke, globe	T1
Asparagus	0.02
Assorted tropical and sub-tropical fruits – inedible peel [except avocado; mango]	5
Avocado	3
Banana passionfruit	5
Bearberry	T5
Beetroot	T*0.1
Bilberry	T5
Bilberry, bog	T5
Bilberry, red	T5
Blackberries	T5
Blueberries	T5
Boysenberry	0.02
Broccoli	T0.3
Cabbages, head	T0.2
Cactus fruit	5
Carrot	T0.3
Cauliflower	T0.3
Celery	T0.5
Cherries	T0.2
Citrus fruits	5
Cranberry	T5
Elderberries	0.02
Grapes	T*0.1
Legume vegetables	T2
Melons, except watermelon	T5
Onion, bulb	0.7
Parsnip	T0.3
Peppers, Chili	T5
Potato	0.1
Pulses	T0.5
Radish	T3
Raspberries, red, black	T5
Rhubarb	0.7
Rollinia	5
Santols	5
Squash, summer (including zucchini)	0.7
Stone fruits [except cherries]	T*0.02
Sweet corn (corn-on-the-cob)	T0.3
Sweet potato	0.1
Turnip, garden	*0.2
Watermelon	T5
Wheat bran, processed	T1
Fenpropathrin Fenpropathrin	
Cherries	5
Citrus fruits	2
Fenpyroximate Fenpyroximate	
Citrus fruits	0.6

Glyphosate Sum of glyphosate and Aminomethylphosphonic acid (AMPA) metabolite, expressed as glyphosate	
Cereal grains [except barley; maize; sorghum; wheat]	T*0.1
Maize	5
Hexazinone Hexazinone	
Blueberries	0.6
Indoxacarb Sum of indoxacarb and its <i>R</i> -isomer	
Stone fruits	2
Novaluron Novaluron	
Cranberry	0.45
Phosmet Sum of phosmet and its oxygen analogue, expressed as phosmet	
Blueberries	10
Lemon	5
Mandarins	5
Pyridaben Pyridaben	
Citrus fruits	0.5
Pyrimethanil Pyrimethanil	
Citrus fruits [except lemon]	10
Lemon	11

”

[1.4] omitting from Schedule 1, under the entries for the following chemicals, the MRL for the named food, substituting

“

Abamectin Sum of avermectin B1a, avermectin B1b and (Z)-8,9 avermectin B1a, and (Z)-8,9 avermectin B1b	
Citrus fruits	0.02
Azoxystrobin Azoxystrobin	
Citrus fruits	10
Carbendazim Sum of carbendazim and 2-aminobenzimidazole, expressed as carbendazim	
Banana	T1
Berries and other small fruits [except grapes]	T5
Ginger, root	T10
Grapes	0.3
Sugar cane	T0.1
Chlorpyrifos Chlorpyrifos	
Peanut	0.05

Cyprodinil Cyprodinil	
Stone fruits	2
Dimethoate Sum of dimethoate and omethoate, expressed as dimethoate <i>see also</i> Omethoate	
Cereal grains	T0.5
Edible offal (mammalian)	0.1
Oilseed [except peanut]	T0.1
Peanut	T*0.05
Peppers, Sweet	0.7
Strawberry	0.02
Tomato	0.02
Glyphosate Sum of glyphosate and Aminomethylphosphonic acid (AMPA) metabolite, expressed as glyphosate	
Rape seed (canola)	20
Mandipropamid Mandipropamid	
Grapes	2
Metrafenone Metrafenone	
Grapes	4.5
Spinetoram Sum of Ethyl-spinosyn-J and Ethyl-spinosyn-L	
Citrus fruits	3

”

Attachment B – Explanatory Statement

1. Authority

Section 13 of the *Food Standards Australia New Zealand Act 1991* (the FSANZ Act) provides that the functions of Food Standards Australia New Zealand (the Authority) include the development of standards and variations of standards for inclusion in the *Australia New Zealand Food Standards Code* (the Code).

Division 2 of Part 3 of the FSANZ Act specifies that the Authority may prepare a proposal for the development or variation of food regulatory measures, including standards. This Division also stipulates the procedure for considering a proposal for the development or variation of food regulatory measures.

FSANZ prepared Proposal M1008 to amend certain MRLs for residues of agricultural and veterinary chemicals. The Authority considered the Proposal in accordance with Division 2 of Part 3 and has approved a draft Standard.

Following consideration by COAG Legislative and Governance Forum on Food Regulation⁶, section 92 of the FSANZ Act stipulates that the Authority must publish a notice about the standard or draft variation of a standard.

Section 94 of the FSANZ Act specifies that a standard, or a variation of a standard, in relation to which a notice is published under section 92 is a legislative instrument, but is not subject to parliamentary disallowance or sunseting under the *Legislative Instruments Act 2003*.

2. Purpose and operation

The purpose of the variation to Standard 1.4.2 is to vary MRLs for residues of agricultural and veterinary chemicals in food.

Standard 1.4.2 lists the limits for agricultural and veterinary chemical residues which may occur in foods. If a limit is not listed for a particular agricultural or veterinary chemical/food combination, there must be no detectable residues of that chemical in that food. This general prohibition means that, in the absence of the relevant limit in the Code, food may not be sold where there are detectable residues.

MRL variations may be required to permit the sale of foods containing legitimate residues. These are technical amendments following changes in use patterns of agricultural and veterinary chemicals available to chemical product users. These changes include both the development of new products and crop uses, and the withdrawal of older products following review. In regard to Australia's WTO obligations, limits may be harmonised with international or trading partner standards. Internationally, farmers face different pest and disease pressures, agricultural and veterinary chemical use patterns and the legitimate residues in food associated with these uses may vary accordingly.

A dietary exposure assessment is conducted before MRLs are varied to ensure that proposed limits do not present any public health or safety concerns.

⁶ Previously known as the Australia and New Zealand Food Regulation Ministerial Council

3. Documents incorporated by reference

The variations to food regulatory measures do not incorporate any documents by reference.

4. Consultation

In accordance with the procedure in Division 2 of Part 3 of the FSANZ Act, the Authority's consideration of Proposal M1008 has included one round of public consultation following an assessment and preparation of draft variations to Standard 1.4.2 and associated reports. Submissions were called for on 17 July 2012 for a four-week consultation period.

A Regulation Impact Statement (RIS) was not required because the proposed variations to Standard 1.4.2 are minor and do not substantially alter existing arrangements. Business compliance costs and other impacts on business, individuals, regulatory agencies and the economy are low or nil. The regulatory proposal does not impose impacts on business, individuals, regulatory agencies or the economy that warrant further analysis. The changes to regulation are machinery in nature involving technical variations to the Standard, which will not have appreciable impacts and are consistent with existing policy.

5. Statement of compatibility with human rights

This instrument is exempt from the requirements for a statement of compatibility with human rights as it is a non-disallowable instrument under section 94 of the FSANZ Act.

6. Variations

Items 1.1 to 1.4 set out amendments to Schedule 1 of Standard 1.4.2.

Item 1.1

This item inserts new entries for the chemicals listed. The entries include the chemical name, residue definition, foods and associated MRLs. This item incorporates the new entries in alphabetical order among the chemicals listed in the Schedule. This item will also result in Schedule 1 containing two chemical residue definitions related to dicamba.

Item 1.2

This item omits the foods and associated MRLs for the chemicals listed.

Item 1.3

This item inserts the foods and associated MRLs for the chemicals listed. It incorporates the new entries in alphabetical order among the foods listed under each chemical.

Item 1.4

This item omits the MRL for the foods listed, replacing it with the limit shown for each of the chemicals listed.

Attachment C – MRLs proposed in relation to MRL harmonisation requests

Chemical	Commodity descriptor	MRL (mg/kg)	Trading partner/Codex
Abamectin	Citrus fruit	0.02	United States of America
Acequinocyl	Citrus fruits	0.2	United States of America
Acetamiprid	Citrus fruit	0.5	United States of America
	Cranberry	0.6	United States of America
Azoxystrobin	Citrus fruits	10	United States of America
Bifenazate	Cranberry	1.5	United States of America
Carbendazim	Apple	0.2	European Union
	Apricot	2	Codex
	Cherries	0.5	European Union
	Citron	0.7	European Union
	Grapefruit	0.2	European Union
	Grapes	0.3	European Union
	Lemon	0.7	European Union
	Lime	0.7	European Union
	Mandarins	0.7	European Union
	Mineola	0.7	European Union
	Nectarine	0.2	European Union
	Oranges	0.2	European Union
	Peach	0.2	European Union
	Pear	0.2	European Union
	Shaddock (pomelo)	0.2	European Union
	Tangelo [except mineola]	0.2	European Union
	Tangors	0.7	European Union
	Tomato	0.5	Codex
Chlorantraniliprole	Cranberry	1	United States of America
Chlorpyrifos	Peanut	0.05	European Union
Clothianidin	Cranberry	0.01	United States of America
Cyfluthrin	Citrus fruits	0.2	United States of America
	Stone fruits	0.3	United States of America
Cypermethrin	Stone fruits	1	United States of America
Cyprodinil	Stone fruits	2	United States of America
Dicamba	Soya bean (immature seeds)	10	United States of America
Difenoconazole	Dried grapes	6	United States of America
	Grapes	4	United States of America
Dimethoate	Boysenberry	0.02	European Union
	Cherries	0.2	European Union
	Elderberries	0.02	European Union
	Strawberry	0.02	European Union
Fenpropathrin	Cherries	5	United States of America
	Citrus fruits	2	United States of America
Fenpyroximate	Citrus fruits	0.6	United States of America
Fluoxastrobin	Cranberry	1.9	United States of America
Fluxapyroxad	Plums (including prunes)	3	United States of America
	Pome fruits	0.8	United States of America
	Pulses [except soya bean(dry)]	0.4	United States of America
	Soya bean (dry)	0.3	United States of America
	Soya bean (immature seeds)	0.15	United States of America
	Stone fruits [except plums (including prunes)]	2	United States of America
Glyphosate	Maize	5	United States of America

Chemical	Commodity descriptor	MRL (mg/kg)	Trading partner/Codex
	Rape seed (canola)	20	United States of America
Hexazinone	Blueberries	0.6	United States of America
Indoxacarb	Stone fruits	2	United States of America
Mandipropamid	Grapes	2	United States of America
Metrafenone	Grapes	4.5	United States of America
Novaluron	Cranberry	0.45	United States of America
Phosmet	Blueberries	10	United States of America
	Lemon	5	United States of America
	Mandarins	5	United States of America
Pyridaben	Citrus fruits	0.5	United States of America
Pyrimethanil	Citrus fruits [except lemon]	10	United States of America
	Lemon	11	United States of America
Spinetoram	Citrus fruits	3	United States of America
Spirodiclofen	Citrus fruits	0.5	United States of America
	Stone fruits	1	United States of America
Spiromesifen	Cranberry	2	United States of America

Attachment D – Dietary exposure estimates

Chemical Commodity descriptor	MRL (mg/kg)	Dietary Exposure Estimates	
Abamectin		NEDI [†] : 64% of the ADI NESTI [‡] as % of the ARfD <u>2-6 years</u> <u>2+ years</u>	
Citrus fruit	0.02	93	29
Acequinocyl		NEDI: 2% of the ADI	
Citrus fruits	0.2		
Acetamiprid		NEDI: 2% of the ADI NESTI as % of the ARfD <u>2-6 years</u> <u>2+ years</u>	
Citrus fruit	0.5	83	27
Cranberry	0.6	<1	<1
Azoxystrobin		NEDI: 31% of the ADI	
Citrus fruits	10		
Bifenazate		NEDI: 18% of the ADI NESTI as % of the ARfD <u>2-6 years</u> <u>2+ years</u>	
Cranberry	1.5	<1	<1
Carbendazim		NEDI: 19% of the ADI NESTI as % of the ARfD <u>2-6 years</u> <u>2+ years</u>	
Apple	0.2	22	6
Apricot	2	46	23
Banana	T1	47	13
Berries and other small fruits [except grapes]	T5	94	24
Cherries	0.5	16	3
Citron	0.7	28	8
Ginger, root	T10	3	3
Grapefruit	0.2	66	9
Grapes	0.3	20	9
Lemon	0.7	28	8
Lime	0.7	19	5
Mandarins	0.7	38	11
Mineola	0.7	38	11
Nectarine	0.2	11	5
Onion, bulb	T*0.2	4	2
Oranges	0.2	29	10
Peach	0.2	31	11
Pear	0.2	14	4
Shaddock (pomelo)	0.2	66	9
Sugar cane	T0.1	2	1
Tangelo [except mineola]	0.2	66	9
Tangors	0.7	66	9
Tomato	0.5	22	9
Chlorantraniliprole		NEDI: <1% of the ADI	
Cranberry	1		
Chlorpyrifos		NEDI: 85% of the ADI NESTI as % of the ARfD <u>2-6 years</u> <u>2+ years</u>	
Peanut	0.05	<1	<1
Clothianidin		NEDI: 6% of the ADI NESTI as % of the ARfD <u>2-6 years</u> <u>2+ years</u>	
Cranberry	0.01	<1	<1

Chemical Commodity descriptor	MRL (mg/kg)	Dietary Exposure Estimates	
Cyfluthrin		NEDI: 40% of the ADI NESTI as % of the ARfD <u>2-6 years</u> <u>2+ years</u>	
Citrus fruits	0.2	83	27
Stone fruits	0.3	30	9
Cypermethrin		NEDI: 12% of the ADI NESTI as % of the ARfD <u>2-6 years</u> <u>2+ years</u>	
Stone fruits	1	86	32
Cyprodinil		NEDI: 25% of the ADI	
Stone fruits	2		
Dicamba		NEDI: 12% of the ADI NESTI as % of the ARfD <u>2-6 years</u> <u>2+ years</u>	
Soya bean (immature seeds)	10	10	3
Difenoconazole		NEDI: 27% of the ADI NESTI as % of the ARfD <u>2-6 years</u> <u>2+ years</u>	
Dried grapes	6	3	<1
Grapes	4	67	30
Dimethoate		NEDI: 86% of the ADI NESTI as % of the ARfD <u>2-6 years</u> <u>2+ years</u>	
Artichoke, globe	T1	59	27
Asparagus	0.02	1	<1
Assorted tropical and sub-tropical fruits – inedible peel* (includes abiu, banana passionfruit, cactus fruit, rollinia, santols) [except avocado; mango]*	5	69	32
Avocado	3	45	8
Bearberry	T5	43	11
Beetroot	T*0.1	31	9
Bilberry	T5	43	11
Bilberry, bog	T5	43	11
Bilberry, red	T5	43	11
Blackberries	T5	69	17
Blueberries	T5	43	11
Boysenberry	0.02	43	11
Broccoli	T0.3	49	16
Cabbages, head	T0.2	13	10
Carrot	T0.3	31	10
Cauliflower	T0.3	39	15
Celery	T0.5	37	11
Cereal grains	T0.5	5	2
Cherries	T0.2	7	1
Citrus fruits	5	74	32
Cranberry	T5	43	11
Edible offal (mammalian)	0.1	3	9
Elderberries	0.02	43	11
Grapes	T*0.1	67	30
Legume vegetables	T2	98	55
Melons, except watermelon	T5	58	40
Oilseed [except peanut]	T0.1	3	2
Onion, bulb	0.7	83	39
Parsnip	T0.3	38	11
Peanut	T*0.05	4	2
Peppers, Chili	T5	5	14
Peppers, Sweet	0.7	52	23
Potato	0.1	37	8
Pulses	T0.5	4	4

Chemical Commodity descriptor	MRL (mg/kg)	Dietary Exposure Estimates	
Radish	T3	77	31
Raspberries, red, black	T5	69	17
Rhubarb	0.7	70	69
Squash, summer (including zucchini)	0.7	71	20
Stone fruits [except cherries]	T*0.02	13	5
Strawberry	0.02	1	<1
Sweet corn (corn-on-the-cob)	T0.3	80	22
Sweet potato	0.1	37	8
Tomato	0.02	8	3
Turnip, garden	*0.2	20	11
Watermelon	T5	58	59
Wheat bran, processed	T1	<1	1
Fenpropathrin		NEDI: 17% of the ADI	
Cherries	5		
Citrus fruits	2		
Fenpyroximate		NEDI: 39% of the ADI NESTI as % of the ARfD	
		<u>2-6 years</u>	<u>2+ years</u>
Citrus fruits	0.6	47	34
Fluoxastrobin		NEDI: <1% of the ADI	
Cranberry	1.9		
Fluxapyroxad		NEDI: 15% of the ADI	
Plums (including prunes)	3		
Pome fruits	0.8		
Pulses [except soya bean(dry)]	0.4		
Soya bean (dry)	0.3		
Soya bean (immature seeds)	0.15		
Stone fruits [except plums (including prunes)]	2		
Glyphosate		NEDI: 9% of the ADI	
Maize	5		
Rape seed (canola)	20		
Hexazinone		NEDI: 1% of the ADI	
Blueberries	0.6		
Indoxacarb		Dietary exposure assessment not required as the variations made did not change the permitted levels of indoxacarb residues in any food.	
Stone fruits	2		
Mandipropamid		NEDI: 4% of the ADI	
Grapes	2		
Metrafenone		NEDI: 2% of the ADI	
Grapes	4.5		
Novaluron		NEDI: 16% of the ADI	
Cranberry	0.45		
Phosmet		NEDI: 39% of the ADI NESTI as % of the ARfD	
		<u>2-6 years</u>	<u>2+ years</u>
Blueberries	10	3	12
Lemon	5	49	14
Mandarins	5	67	19
Pyridaben		NEDI: 60% of the ADI NESTI as % of the ARfD	
		<u>2-6 years</u>	<u>2+ years</u>
Citrus fruits	0.5	51	16
Pyrimethanil		NEDI: 10% of the ADI NESTI as % of the ARfD	
		<u>2-6 years</u>	<u>2+ years</u>
Citrus fruits [except lemon]	10	84	29

Chemical Commodity descriptor	MRL (mg/kg)	Dietary Exposure Estimates
Lemon	11	26 7
Spinetoram Citrus fruits	3	NEDI: 14% of the ADI
Spirodiclofen Citrus fruits Stone fruits	0.5 1	NEDI: 25% of the ADI
Spiromesifen Cranberry	2	NEDI: <1% of the ADI

[†] The National Estimated Daily Intake (NEDI) represents an estimate of chronic dietary exposure from the whole diet for the general population aged 2 years and over, expressed in this table as a proportion of the relevant Acceptable Daily Intake (ADI).

[‡] The National Estimated Short Term Intake (NESTI), represents an estimate of acute dietary exposure from individual foods or food groups for the general population aged 2 years and over and for young children, expressed in this table as a proportion of the relevant Acute Reference Dose (ARfD), where established.

Further information on dietary exposure assessments is available at

<http://www.foodstandards.gov.au/scienceandeducation/scienceinfsanz/dietaryexposureassessmentsatfsanz/>.

**SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
REFERENCES COMMITTEE**

Inquiry into the review of the citrus industry in Australia

Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013 and Thursday, 4 July 2013

Griffith and District Citrus Growers (GDCG)

Written Questions on Notice - Senator Ruston

Question 1	Membership	Can GDCG please advise the following: • exact number of current members; • the method by which membership is gained; and • the annual membership fee.

**SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
REFERENCES COMMITTEE**

Inquiry into the review of the citrus industry in Australia

Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013 and Thursday, 4 July 2013

Griffith and District Citrus Growers (GDCG)

Written Questions on Notice - Senator Ruston

Question 1	Membership	Can GDCG please advise the following: • exact number of current members: 56 • The method by which membership is gained: <i>Forms for application for membership (new members) sent out to farmers. Thereafter membership renewals will be sent yearly.</i> • The annual membership fee: \$20.00

Please note: Reason for sending out application for membership is that prior no formal membership format existed and a new membership register is to be implemented.

**SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
REFERENCES COMMITTEE**

Inquiry into the review of the citrus industry in Australia

Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013 and Thursday, 4 July 2013

Horticulture Australia Ltd (HAL) and the Citrus Industry Advisory Committee (Citrus IAC)

Written Questions on Notice - Senator Ruston

Question 1	R&D General	In evidence a number of witnesses stated that objective R&D has collapsed. There was concern expressed that a large number of researchers were leaving the space because they were no longer successful in any applications for funding. Can you provide the following data for the years 2008-09, 2009-10, 2010-11, 2011-12 and 2012-13: • the number of R&D submissions received by HAL; • the number of submissions received by HAL from Citrus Australia Ltd; • the number of Citrus Australia Ltd submissions approved; and • the percentage of total funds approved for Citrus Australia Ltd projects. <i>Please note that the request is for the projects submitted and accessed in the stated years, not the funds remitted in the year.</i>
Question 2	Deed of Agreement 2010-14	Can HAL advise that it is satisfied that no funds have been paid to the Peak Industry Body (PIB) for the Australian citrus industry, Citrus Australia Ltd, for the purposes of: • agri-political activity; • sitting fees; • salaries and running costs of the PIB other than those directly attributable to consultations with the HAL and the PIB constituency on matters which it is progressing with HAL; or • capital expenditure. Can HAL also provide evidence that it has governance arrangements in place that are sufficiently transparent to enable HAL to be assured that Citrus Australia Ltd is not using any HAL allocated funds for the above listed purposes?
Question 3	Deed of Agreement 2010-14	Does HAL place any limitation on the quantum of the R&D funds that can be allocated to Peak Industry Body (PIB) consultation and program funding? Does HAL provide PIBs with a template for eligible industry consultation, and if so, can HAL provide a copy of this template and full details of approved Citrus Australia Ltd consultation funding projects since 2009?

Question 4	R&D	Can HAL advise of quantum of citrus R&D funds spent on actual research and development in the years 2008-09, 2009-10, 2010-11, 2011-12 and 2012-13? Can HAL further advise the quantum of citrus R&D funds spent on project management, consultation and other non-R&D activities?
Question 5	Citrus IAC	Is HAL able to appoint the chair or any other member of the Citrus IAC without the agreement of Citrus Australia Ltd? Can HAL advise if the current Chair of the Citrus IAC was recommended for appointment by Citrus Australia Ltd or HAL?
Question 6	Citrus IAC	During the hearing, Senator Xenophon requested that the minutes of the Citrus IAC since 2010 be made available to the Committee. Can these be provided to the Secretariat?
Question 7	Citrus IAC	Can HAL provide copies of the minutes of its meetings when the membership of the current Citrus IAC was discussed, including teleconferences?
Question 8	Citrus IAC	Can HAL provide the names of the people on the current Citrus IAC and indicate if any of the members, or their employers, are currently members, or have been members in the past, of any of the following bodies: • Citrus Australia Ltd Board; • selection panel for the Citrus Australia Ltd Board ; • Australian Citrus Growers Federation; • the IAC Technical Reference Committee; • selection panel for the appointment of the IAC Technical Reference Committee; • selection panel for the appointment of the Citrus IAC; and • Citrus Australia Ltd.
Question 9	Citrus IAC	Can HAL provide details of the process by which the current Citrus IAC members were selected? This information should include: • the name of the recruitment agency and the names of the actual staff who worked on the process; • whether any of the principals or staff of this agency have ever been employed by Citrus Australia Ltd, or been a director of Citrus Australia Ltd; • the names of the people on the selection committee, noting whether any are members of any of the following bodies: ▪ the Citrus Australia Ltd Board; ▪ the current or previous Citrus IAC; ▪ the selection panel for the Citrus Australia Ltd Board ; ▪ the IAC Technical Reference Committee; ▪ the selection panel for the appointment of the IAC Technical Reference Committee; ▪ Citrus Australia Ltd; • the number of applicants for the positions; • criteria against which applications were measured; • the number of applicants on the short list; and • the number of applicants interviewed.

Question 10	Citrus IAC Technical Committee	Can HAL provide a list of the people appointed to the IAC Technical Reference Committee, including: • details of employers if relevant; • the process for assessment of technical expertise, including the details and formal qualifications of the successful applications; and • the names of the people who were responsible for the selection of the members of this Reference Committee?
Question 11	Project assessment	Can HAL advise of the mechanism by which projects are assessed against the Australian Citrus Strategic R&D Plan?
Question 12	Project outcomes	Can HAL advise where levy payers can obtain detailed information, including milestone reports, on levy-funded marketing and research and development projects.
Question 13	CT09055	Can HAL provide the following information in relation to CT09055: • has the project been completed; • if this project has been completed, the total amount of levy funds applied to this project; • if it has not been completed, advise of the total amount of levy funds applied to this project to date; • the objectives against which this project was measured; • whether these objectives were the original objectives as assessed by the Citrus IAC when the project was first submitted for funding and approved; and • the process by which the original objectives were changed midway through the project.
Question 14	Five-year Investment Plan	Can HAL provide a copy of the paper prepared by Citrus Australia Ltd, HAL, the Citrus IAC and NHRN that was submitted to Citrus IAC in late 2012 recommending a process for achieving program development in a transparent manner?

**SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
REFERENCES COMMITTEE**

Inquiry into the review of the citrus industry in Australia

Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013 and Thursday, 4 July 2013

Horticulture Australia Ltd (HAL) and the Citrus Industry Advisory Committee (Citrus IAC)

Written Questions on Notice - Senator Ruston

Question 1	R&D General	In evidence a number of witnesses stated that objective R&D has collapsed. There was concern expressed that a large number of researchers were leaving the space because they were no longer successful in any applications for funding. Can you provide the following data for the years 2008-09, 2009-10, 2010-11, 2011-12 and 2012-13: - the number of R&D submissions received by HAL; - the number of submissions received by HAL from Citrus Australia Ltd; - the number of Citrus Australia Ltd submissions approved; and - the percentage of total funds approved for Citrus Australia Ltd projects. <i>Please note that the request is for the projects submitted and accessed in the stated years, not the funds remitted in the year.</i>																														
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	2010-14	• agri-political activity; • sitting fees; • salaries and running costs of the PIB other than those directly attributable to consultations with the HAL and the PIB constituency on matters which it is progressing with HAL; or • capital expenditure. Can HAL also provide evidence that it has governance arrangements in place that are sufficiently transparent to enable HAL to be assured that Citrus Australia Ltd is not using any HAL allocated funds for the above listed purposes?
Answer 2		Based on reporting provided to HAL by Citrus Australia Limited, HAL has no indication that consultation funding has been used by Citrus Australia Limited for anything other than the purposes for it was provided as per HAL's agreement with Citrus Australia Limited. Specifically for: • agri-political activity; • sitting fees (for CAL Directors); • salaries and running costs of the PIB other than those directly attributable to consultations with the HAL and the PIB constituency on matters which it is progressing with HAL; or • capital expenditure. From an R&D perspective, capital expenditure within projects does occur in line with HAL's policy on Capital Items. It is not a regular component of requests for R&D funds but it does happen. The HAL policy deals with the purchase, value and disposal of the asset at the end of the project. There is no expenditure on agri-political activity funded by HAL. In all communications projects the default funding level is 75% of the total requested with a clear acknowledgement that PIBs do often get funds from other sources which they may use on other activities. This is monitored very closely. In some instances, where a PIB can demonstrate that it gets no outside funding from other sources, this % funding can increase. No sitting fees are paid for through R&D projects. No salaries/running costs of PIBS other than those directly associated with HAL projects are paid from R&D project funding. An IDO project that funds a range of agreed activities does often reside within a PIB, however the funding of these agreed activities is completely separate. When HAL feels the PIB is the most appropriate entity to carry out a R&D project, normally in the capacity building discipline, all the activities of the project are costed and funded separately. Again this role may reside within the PIB. HAL carefully monitors PIB FTE to ensure there is no 'double dipping' of funding.
Question 3	Deed of Agreement 2010-14	Does HAL place any limitation on the quantum of the R&D funds that can be allocated to Peak Industry Body (PIB) consultation and program funding? Does HAL provide PIBs with a template for eligible industry consultation, and if so, can HAL provide a copy of this template and full details of approved Citrus Australia Ltd consultation funding projects since 2009?

Answer 3		Limitation of funding – No. Template for eligible – Yes (refer to attachment). Past consultation funding: <table><tr><td>2008/09</td><td>\$184,400</td></tr><tr><td>2009/10</td><td>172,650</td></tr><tr><td>2010/11</td><td>171,479</td></tr><tr><td>2011/12</td><td>161,479</td></tr><tr><td>2012/13</td><td>159,480</td></tr></table>	2008/09	\$184,400	2009/10	172,650	2010/11	171,479	2011/12	161,479	2012/13	159,480														
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Answer 4		HAL utilised industry R&D levy and matched funding from the Federal Government only for appropriate R&D activities. The table below shows the level of funding from both matched R&D levy and matched Voluntary Contributions over the last five years. Within some HAL projects there are management costs which are considered to be appropriate R&D activities when contracted. Prior to contracting, these projects and their costs were assessed by HAL R&D Services Portfolio Managers and the Citrus IAC and modified where required. Consultation funding to Citrus Australia Limited was paid in accordance with the guidelines outlined in the statutory funding agreement. <table><tr><th>YEAR</th><th>Matched R&D Levy (\$)</th><th>Matched VC (\$)</th><th>Consultation Agreement Matched R&D</th></tr><tr><td>2008-09</td><td>\$1,812,156</td><td>\$1,794,723</td><td>\$158,150</td></tr><tr><td>2009-10</td><td>\$1,815,721</td><td>\$1,389,688</td><td>\$146,400</td></tr><tr><td>2010-11</td><td>\$2,081,696</td><td>\$2,205,078</td><td>\$115,229</td></tr><tr><td>2011-12</td><td>\$2,388,887</td><td>\$1,905,718</td><td>\$102,230</td></tr><tr><td>2012-13</td><td>\$2,221,207</td><td>\$1,549,842</td><td>\$102,584</td></tr></table>	YEAR	Matched R&D Levy (\$)	Matched VC (\$)	Consultation Agreement Matched R&D	2008-09	\$1,812,156	\$1,794,723	\$158,150	2009-10	\$1,815,721	\$1,389,688	\$146,400	2010-11	\$2,081,696	\$2,205,078	\$115,229	2011-12	\$2,388,887	\$1,905,718	\$102,230	2012-13	\$2,221,207	\$1,549,842	\$102,584
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Question 5	Citrus IAC	Is HAL able to appoint the chair or any other member of the Citrus IAC without the agreement of Citrus Australia Ltd? Can HAL advise if the current Chair of the Citrus IAC was recommended for appointment by Citrus Australia Ltd or HAL?
Answer 5		Yes. The current IAC Chair was recommended to HAL by the Australian Citrus Growers, the Prescribed Industry Body for the citrus statutory levy at the time.
Question 6	Citrus IAC	During the hearing, Senator Xenophon requested that the minutes of the Citrus IAC since 2010 be made available to the Committee. Can these be provided to the Secretariat?
Answer 6		This response will be considered by the HAL Board which next meets on 1 August, 2013. An answer will be provided following the Board meeting.
Question 7	Citrus IAC	Can HAL provide copies of the minutes of its meetings when the membership of the current Citrus IAC was discussed, including teleconferences?
Answer 7		This response will also be considered by the HAL Board which next meets on 1 August, 2013. An answer will be provided following the Board meeting.
Question 8	Citrus IAC	Can HAL provide the names of the people on the current Citrus IAC and indicate if any of the members, or their employers, are currently members, or have been members in the past, of any of the following bodies: • Citrus Australia Ltd Board; • selection panel for the Citrus Australia Ltd Board; • Australian Citrus Growers Federation; • the IAC Technical Reference Committee; • selection panel for the appointment of the IAC Technical Reference Committee; • selection panel for the appointment of the Citrus IAC; and • Citrus Australia Ltd.

Answer 8		Ordinary membership of the prescribed industry body is not a selection criteria of HAL IAC membership. <table><tr><th>IAC Member</th><th>Citrus Australia Ltd Board</th><th>Selection panel for Citrus Australia Board</th><th>Australian Citrus Growers Federation</th><th>IAC Technical Reference Committee</th><th>Selection panel for appointment of the IAC Technical Reference Committee</th><th>Selection panel for the appointment of the Citrus IAC (July 2012)</th><th>Citrus Australia Ltd. (ordinary member)</th></tr><tr><td>Mr Michael Crook</td><td>No</td><td>Not known</td><td>Not known</td><td>No</td><td>No</td><td>Yes</td><td>Yes</td></tr><tr><td>Ms Tania Chapman</td><td>Yes</td><td>Not known</td><td>Not known</td><td>No</td><td>No</td><td>Yes</td><td>Yes</td></tr><tr><td>Mr Kevin Cock</td><td>Yes</td><td>Not known</td><td>Not known</td><td>No</td><td>No</td><td>No</td><td>Yes</td></tr><tr><td>Mr Greg Dhnaram</td><td>Yes</td><td>Not known</td><td>Not known</td><td>No</td><td>No</td><td>No</td><td>Not known</td></tr><tr><td>Mr John Lawrenson</td><td>No</td><td>Not known</td><td>Not known</td><td>No</td><td>No</td><td>No</td><td>Not known</td></tr><tr><td>Mr Richard Findlay</td><td>No</td><td>Not known</td><td>Not known</td><td>No</td><td>No</td><td>No</td><td>Not known</td></tr><tr><td>Mr Wayne Parr</td><td>No</td><td>Not known</td><td>Not known</td><td>No</td><td>No</td><td>No</td><td>Yes</td></tr><tr><td>Mr Richie Roberts</td><td>No</td><td>Not known</td><td>Not known</td><td>No</td><td>No</td><td>No</td><td>Not known</td></tr><tr><td>Mr Gavin Foord</td><td>No</td><td>Not known</td><td>Not known</td><td>No</td><td>No</td><td>No</td><td>Not known</td></tr></table>	IAC Member	Citrus Australia Ltd Board	Selection panel for Citrus Australia Board	Australian Citrus Growers Federation	IAC Technical Reference Committee	Selection panel for appointment of the IAC Technical Reference Committee	Selection panel for the appointment of the Citrus IAC (July 2012)	Citrus Australia Ltd. (ordinary member)	Mr Michael Crook	No	Not known	Not known	No	No	Yes	Yes	Ms Tania Chapman	Yes	Not known	Not known	No	No	Yes	Yes	Mr Kevin Cock	Yes	Not known	Not known	No	No	No	Yes	Mr Greg Dhnaram	Yes	Not known	Not known	No	No	No	Not known	Mr John Lawrenson	No	Not known	Not known	No	No	No	Not known	Mr Richard Findlay	No	Not known	Not known	No	No	No	Not known	Mr Wayne Parr	No	Not known	Not known	No	No	No	Yes	Mr Richie Roberts	No	Not known	Not known	No	No	No	Not known	Mr Gavin Foord	No	Not known	Not known	No	No	No	Not known
IAC Member	Citrus Australia Ltd Board	Selection panel for Citrus Australia Board	Australian Citrus Growers Federation	IAC Technical Reference Committee	Selection panel for appointment of the IAC Technical Reference Committee	Selection panel for the appointment of the Citrus IAC (July 2012)	Citrus Australia Ltd. (ordinary member)																																																																											
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Mr Kevin Cock	Yes	Not known	Not known	No	No	No	Yes																																																																											
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Mr Gavin Foord	No	Not known	Not known	No	No	No	Not known																																																																											
Question 9	Citrus IAC	Can HAL provide details of the process by which the current Citrus IAC members were selected? This information should include: - the name of the recruitment agency and the names of the actual staff who worked on the process; - whether any of the principals or staff of this agency have ever been employed by Citrus Australia Ltd, or been a director of Citrus Australia Ltd; - the names of the people on the selection committee, noting whether any are members of any of the following bodies: - the Citrus Australia Ltd Board; - the current or previous Citrus IAC; - the selection panel for the Citrus Australia Ltd Board ; - the IAC Technical Reference Committee; - the selection panel for the appointment of the IAC Technical Reference Committee; - Citrus Australia Ltd; - the number of applicants for the positions; - criteria against which applications were measured; - the number of applicants on the short list; and - the number of applicants interviewed.																																																																																
Answer 9		Selection process Print advertisements seeking expressions of interest for vacancies on the Citrus IAC placed in the regional publications appropriate for the major growing regions (Central Queensland, NSW Riverina, Murray Valley, SA																																																																																

		Riverland and WA). The advertisement included the following extract: ‘HAL is seeking to appoint appropriate skilled and passionate persons that can demonstrate the following competencies: • Extensive industry experience – in production and marketing • Strong commercial agribusiness acumen • Export market access/export marketing • Biosecurity and plant health • Agricultural communication and extension • National industry perspective’ 2. The expression of interest advertisement was also broadcast via CAL’s electronic newsletter service and on both the CAL and HAL websites. 3. Eleven (11) applications were received by the closing date of 20 July 2012. 4. Applications were provided to HAL’s external Sydney based recruitment agency, Launch Recruitment, for an independent review of CV’s of all candidates. The Launch Recruitment employee that conducted the review was Managing Director, Ms Rebecca Wallace. Ms Wallace, or any of the Launch recruitment staff, have never been employed by Citrus Australia Limited, or been a director of Citrus Australia Limited. 5. A Selection Panel was established by HAL that consisted of: • the current independent IAC Chair, Mr Michael Crook. Mr Crook is understood to be a member of Citrus Australia Limited. • a representative of the Prescribed Industry Body for the Citrus Statutory Levy , Ms Tania Chapman. Ms Chapman is a current member of the IAC and Chair of Citrus Australia Limited. • a representative of the HAL Board, Mr Darral Ashton. Mr Ashton is a director of HAL; • and representative of HAL’s operational staff, Mr Corey Fitzpatrick. Mr Fitzpatrick holds the position of Industry Services Manager at HAL. 6. The selection panel met on Tuesday 14 July 2012 in Melbourne to review all applications – there was no shortlist. Given that all of the applicants were well known within the industry, it was proposed that in the first instance the Selection Panel assess the written applications rather than conduct interviews, as interviews would have required significant travel arrangements and diary management, would be expensive, and may not provide any greater insight. It was also proposed that should there have been a need for the Selection Panel to gather more information to distinguish between candidates, then there was an option to conduct interviews for any or all of the vacant IAC positions. 7. The Selection Panel used the following methodology in its review of candidates:

		a) Skills gap analysis of continuing IAC member s against the Citrus Industry Strategic Investment Plan (SIP) b) Objective assessment of candidates against the advertised skills criteria, the identified skills deficiencies of the current IAC and key skills requirement as detailed in the Citrus SIP. c) Ranking of candidates based on objective assessment d) Subjective evaluation of top ranked candidates taking into account aspects such as balancing the IAC's representation across regions, the supply chain and levy payer characteristics (eg corporate producer vis-à-vis smaller to medium sized producers). e) Launch Recruitment's candidates assessment were provided to the Selection Panel and considered in regard to the Selection Panel's conclusions for discrepancies and/or consistencies. f) In its conclusion, the Selection Panel determined that there was no requirement for a process of interviews and additional expense. No interviews were therefore conducted. 8. The Selection Panel's top four candidates were provided to the Prescribed Industry Body, Citrus Australia Limited, for review and comment. 9. The CAL board reviewed and endorsed the Selection Panel's candidates nominating them to HAL for appointment to the Citrus IAC on 16 August 2012. 10. HAL appointed Mr Findlay, Mr Roberts, Mr Parr and Mr Foord to the Citrus IAC and notified all successful and non-successful candidates by emailed letter dated 23 August 2013.
Question 10	Citrus IAC Technical Committee	Can HAL provide a list of the people appointed to the IAC Technical Reference Committee, including: • details of employers if relevant; • the process for assessment of technical expertise, including the details and formal qualifications of the successful applications; and • the names of the people who were responsible for the selection of the members of this Reference Committee?
Answer 10		There are currently three members of the Technical Advisory Group. These being: - Shane Hetherington Research Leader, Agriculture NSW [Lead Agency for Citrus under the NHRN] Shane has a PhD from Qld University and has managed R&D for NSW Agriculture in the fruit industries for many years - Brad Wells R&D Strategy implementation Manager, HAL 7 years as Plant Health Portfolio Manager in HAL and agricultural pesticide R&D for 20 years. - Andrew Harty

		General Manager Market Development Citrus Australia Ltd Shane Hetherington replaced Pat Barkley who resigned from her position in September 2012. The selectors for this Reference Committee were the General Manager R&D - David Moore and General Manager IS - Warwick Scherf.
Question 11	Project assessment	Can HAL advise of the mechanism by which projects are assessed against the Australian Citrus Strategic R&D Plan?
Answer 11		The projects are assessed firstly by the relevant HAL Portfolio Manager and then by the Technical Reference Group. Both assessments are conducted with reference to the technical quality and feasibility of the research being offered within the proposal provided. The strategic fit of the proposal is addressed by the Citrus Industry Advisory Committee.
Question 12	Project outcomes	Can HAL advise where levy payers can obtain detailed information, including milestone reports, on levy-funded marketing and research and development projects.
Answer 12		Details of HAL R&D or marketing projects can be found in: • Strategic Investment Plans (details project areas and strategic projects to be or that are currently being undertaken) • Industry annual investment plans (proposed projects to be undertaken for a particular year) • Industry annual reports (full details of all project, funding and service providers for the year) • Online at the relevant industry portal in the HAL website • Directly from the PIB whether a levy payer is a member of the PIB or not • Directly from HAL on request. Final reports are provided free of charge to levy payers for the particular industry. HAL does not make publicly available milestone reports. These are a matter between HAL, the relevant IAC and the service provider undertaking the project and are part of the contract between HAL and the service provider.
Question 13	CT09055	Can HAL provide the following information in relation to CT09055: • has the project been completed; • if this project has been completed, the total amount of levy funds applied to this project; • if it has not been completed, advise of the total amount of levy funds applied to this project to date; • the objectives against which this project was measured; • whether these objectives were the original objectives as assessed by the Citrus IAC when the project was first

		- submitted for funding and approved; and - the process by which the original objectives were changed midway through the project.
Answer 13		- Yes. Project CT09055 has been completed. \$1,029,982 Citrus R&D Levy matched by Federal Government has been applied to this project - n/a. This project has been completed. - The project was measured by the Outputs and Outcomes presented in the original proposal. These did not change throughout the project. <u>Outputs:</u> - The first annual operating plan will be submitted in October 2010, and then annually thereafter - Performance against the AOPs will be reported every six months - Each committee will meet regularly (approximately bimonthly) and report their recommendations to the board of Citrus Australia, with delivery to coincide with board meetings. - Value Chain Coordinators (VCC) will implement board decisions and market requirements, and will provide bimonthly progress reports covering their specialty areas and regions. - Training sessions, workshops and field days will be arranged by VCCs to deliver value chain information at every level; reports on these activities will be published in Australian Citrus News and in regional newsletters. - The GMMD will produce regular national reports highlighting progress throughout the industry, and will present the program at the national conference in November. - An improved national plan for producing new citrus varieties in line with market demand forecasts will be developed and reported to the Citrus Australia board, and implemented following board approval. <u>Outcomes:</u> - Ability to strategically meet the national and regional industry development needs of the industry both now and into the future. - Improved information and understanding of issues relevant to domestic and international markets and market access. - More effective spend of industry levy funds on research projects as they will be better aligned with market requirements. - Greater efficiencies in R&D programs due to a cohesive approach between regional boards and Citrus Australia. - Improved communications throughout the citrus value chain, with resultant improvements in efficiency and better business decision making. - The objectives for project CT09055 have not changed throughout the project.

		• The only changes to the project were to personnel, operational and budget. The reason for those changes in the project were due to: • Originally CT09055 involved two Value Chain Coordinator (VCC) positions in WA, Nathan Hancock and Helen Ramsey. However, a large part of their work was nationally based and required continual travel. - o Helen Ramsey stayed in Western Australia but her activity was removed from this project and incorporated into a separate Western Australian specific IDO project (CT11005). CT11005 was closely aligned with this project (CT09055) and national industry development activities. - o Nathan Hancock moved from Western Australia to Mildura allowing Nathan to spend more focus on quality • The project review at 12 months including industry consultation identified the need to increase resourcing of the Australian Citrus Quality Standards program which Nathan was able to undertake. • The project budget for CT09055 was reduced by \$198,015 or 12.3%.
Question 14	Five-year Investment Plan	Can HAL provide a copy of the paper prepared by Citrus Australia Ltd, HAL, the Citrus IAC and NHRN that was submitted to Citrus IAC in late 2012 recommending a process for achieving program development in a transparent manner?
Answer 14		We assume this question refers to the Citrus Industry's five year Strategic Plan (refer to attachment)



HAL CONSULTATION FUNDING AGREEMENT TEMPLATE 2013/2014

1. These templates are protected so you can only access certain fields.
2. The fields you are required to fill in are identified by yellow shaded cells on the **red** coloured tabs
3. All figures should relate to the financial year 1 July 2013 - 30 June 2014
4. All figures should **exclude** GST

NB: These figures must be verifiable and may be subject to HAL audit at any time

For more information or assistance contact:

IS Manager: _____
Horticulture Australia Limited
Tel:
Email: Industry Services Manager

Guidelines for Activities that are Eligible for Member Consultation Funding

Industry Advisory Committee	
<i>This includes all activities directly related to and expended in the preparation and running of IAC meetings, this includes secretariat functions but excludes preparation time by Member office bearers</i>	
Included: • Travel, accommodation & meals - o for IAC Chair & Members - o IAC sub-committees which are recognised by HAL as providing program advice. - o Presenters or experts • Sitting fees for IAC Chairs and Members - o \$690/day for Chairs - o \$405/day for IAC Members • Secretariat function: - o Member staff time and telecommunications for preparation, attendance and minute taking - o Travel, accommodation and meals for Member staff - o Meeting papers – preparation, publishing, printing & distribution • Enabling costs – teleconferencing, venue & equipment hire and catering • Travel insurance for IAC members	Excluded: • Meeting preparation time by Member office bearers – this is covered under consultation • Sitting fees for ex-officio IAC Members • Costs associated with Member (as opposed to IAC) subcommittees • Excluded unless prior approval from IS manager: - o Attendance at IAC / subcommittees of experts or other non-members - o Meetings of IACs / subcommittees in excess of those stipulated in the annual partnership agreement
Annual Levy Payers Meeting	
<i>This includes all activities directly related to and expended in the preparation and running of annual levy payers meetings</i>	
Included: • Notification of the meeting – advertising & distribution costs • Travel, accommodation & meals for IAC Chairs • Sitting fees for IAC Chairs • Secretariat preparation costs (including Member staff time) • Venue & equipment hire	Excluded: • Preparation time by Member office bearers – covered as part of consultation
Consultation	
<i>This includes activities that is specifically providing advice to HAL on, or aiding in the administration of, HAL industry programs</i>	
Included: • Time, travel, accommodation and meals: - o Project and program development with HAL staff - o Program work in progress meetings with HAL staff - o All ex officio involvement of Member CEO/GM in IAC and ALPM preparation - o Attendance at HAL Industry Forums for Member Chairs, office bearers and designated representatives - o Attendance at IMC meetings for Member CEO's or designated representatives - o Attendance at Board to Board consultation meetings for Member Chairs and staff not covered under other project funding e.g. IDMs • Cost associated with meetings with Government Departments on HAL program related matters • Costs associated with meetings with Government Ministers on HAL program related matters	Excluded but possibly funded by projects : • State and regional industry meetings with levy papers • Participation in non HAL related industry committees • Secretarial/administrative support services to the Member • General industry liaison (processors, suppliers, etc) • Meetings on regulatory issues eg climate change. Excluded – not funded by HAL: • Costs associated with the conducting of Member Board business (travel & accommodation, sitting fees, insurances, honorariums, etc) • Meetings with Government Departments on non HAL program related matters. • Meetings with Government Ministers on non HAL program related matters. • PHA subscriptions and meeting costs are excluded. HAL will be working with PHA to coordinate HAL meeting locations and timings with PHA meetings so that wherever possible industries can offset travel and accommodation costs against fundable HAL activities.

Note - Explicitly HAL will not fund any event or activity that has a component deemed by HAL to be agripolitical.

GENERAL INFORMATION

INDUSTRY NAME:

IRB PAYMENT DETAILS	
Select the applicable payment cycle ☐ Annually Note: Any VC to be received by 31 July Payments will be made 15 September ☐ Six Monthly Note: Any VC to be received by 31 July, 31 January Payments will be made 15 September, 15 March	

SCHEDULE 1 - PAYMENTS 2013/14 -

Page 1

Section 1

PAYMENTS TO IRB

Payments will only be made upon receipt of a tax invoice from the IRB

Industry Selection Required	Managed by IRB			TOTAL
	VC (Matched)	R&D	Marketing	
IAC	\$ -	\$ -	\$ -	\$ -
Annual Levy Payers Meeting	\$ -	\$ -	\$ -	\$ -
Consultation	\$ -	\$ -	\$ -	\$ -

Total	\$ -	\$ -	\$ -	\$ -

MILESTONE PAYMENT TO IRB				\$ -

IRB TO INVOICE
(inclusive of GST)

\$ -

PAYMENT CYCLE:	0	TBA

TOTAL VC CONTRIBUTION REQUIRED PER MILESTONE PAYMENT (includes Across Industry)	\$0.00	TBA

Notes:

All figures are quoted exclusive of GST

DETAILED EXPENSE SUMMARY

INDUSTRY ADVISORY COMMITTEE

	\$	Financial Justification / Explanatory notes
Sitting fees (per meeting)		eg Number of days X daily rate X number of meetings X number of members
IAC Member and secretariat travel and accommodation		
Presenters' travel and accommodation		
Venue hire		
Audio visual hire		
Catering		
Printing and dissemination of papers		
Secretariat support time		
Teleconference Calls		
Other		
TOTAL	-	

ANNUAL LEVY PAYERS MEETING

	\$	Financial Justification / Explanatory notes
Notice of meeting		
Printing and dissemination of papers		
Dissemination of Annual Report		
IAC Chair and secretariat travel and accommodation		
IAC Chair sitting fees for attendance		
Venue hire		
Audio visual hire		
Catering		
Secretariat support time		
Other		
TOTAL	-	

CONSULTATION

	\$	Financial Justification / Explanatory notes
IRB representative attendance at HAL Forums		
HAL MD liaison with CEO		
HAL member consultation mtgs		
CEO attendance at Across Industry Committee		
Prog WIP Mtgs with HAL		
Project Development with HAL staff		
Mtgs with Govt depts and service providers		
Other		
TOTAL	-	

INDUSTRY ADVISORY COMMITTEE

This includes all activities directly related to and expended in the preparation and running of IAC meetings, this includes secretariat functions but excludes preparation time by IRB office bearers

EXPENSES	Managed by IRB			Total
	VC (Matched)	R&D	Marketing	
Sitting fees (per meeting)	\$ -	\$ -	\$ -	\$ -
IAC Member and secretariat travel and accommodation	\$ -	\$ -	\$ -	\$ -
Presenters' travel and accommodation	\$ -	\$ -	\$ -	\$ -
Venue hire	\$ -	\$ -	\$ -	\$ -
Audio visual hire	\$ -	\$ -	\$ -	\$ -
Catering	\$ -	\$ -	\$ -	\$ -
Printing and dissemination of papers	\$ -	\$ -	\$ -	\$ -
Secretariat support time	\$ -	\$ -	\$ -	\$ -
Teleconference Calls	\$ -	\$ -	\$ -	\$ -
Other	\$ -	\$ -	\$ -	\$ -
Total	\$0.00	\$0.00	\$0.00	\$0.00

VC CONTRIBUTION REQUIRED	\$ -

- Notes:
- (1) Should not include costs for any members covered under consultation or any other HAL project. Ex-officio are not eligible for sitting costs.
- (2) Needs to identify meetings, location, teleconferences or face to face, and whether held in conjunction with IRB meetings
- (3) Use IRB personnel cost calculator below for all secretariat support costs (includes time for preparation of meeting papers, preparing minutes, dissemination minutes)

- Additional notes:
- Included:
- Travel, accommodation & meals for IAC Members and secretariat
 - Travel, accommodation & meals for IAC sub-committees which are recognised by HAL as providing program advice.
 - Sitting fees for IAC Chairs and Members
 - Travel, accommodation & meals for Presenters or Experts
 - Teleconferencing costs
 - Venue & equipment hire
 - Catering
 - Publishing, printing & posting meeting papers
 - IRB staff time and telecommunications for preparation/attendance/minutes (secretariat function)
- Excluded:
- Meeting preparation time by IRB office bearers
 - Ex-officio costs other than secretariat
 - Costs associated with IRB (as opposed to IAC) subcommittees
 - Excluded unless prior approval from IS manager:
 - Attendance at IAC / subcommittees of experts or other non-members
 - Meetings of IACs / subcommittees in excess of those stipulated in the annual partnership agreement

IRB personnel time cost calculator - daily rate: Note personnel, daily rate and number of days in Justification/Notes section above.

Expense	CEO	Admin 1	Admin 2	IRB Chair
Salary				
On costs allowable:				
- Superannuation				
- Office rental				
- Phone, computer, fax, printers, copiers				
- Insurance (travel & professional indemnity)				
Total daily rate	0	0	0	0

JUSTIFICATION / EXPLANATORY NOTES

eg Number of days X daily rate X number of meetings X number of members

Contributes to IRB operating costs

ANNUAL LEVY PAYERS MEETING

This includes all activities directly related to and expended in the preparation and running of annual levy payers meetings

EXPENSES	Managed by IRB			Total
	VC (Matched)	R&D	Marketing	
Notice of meeting	\$ -	\$ -	\$ -	\$ -
Printing and dissemination of papers	\$ -	\$ -	\$ -	\$ -
Dissemination of Annual Report	\$ -	\$ -	\$ -	\$ -
IAC Chair and secretariat travel and accommodation	\$ -	\$ -	\$ -	\$ -
IAC Chair sitting fees for attendance	\$ -	\$ -	\$ -	\$ -
Venue hire	\$ -	\$ -	\$ -	\$ -
Audio visual hire	\$ -	\$ -	\$ -	\$ -
Catering	\$ -	\$ -	\$ -	\$ -
Secretariat support time	\$ -	\$ -	\$ -	\$ -
Other	\$ -	\$ -	\$ -	\$ -
Total	\$0.00	\$0.00	\$0.00	\$0.00

VC CONTRIBUTION REQUIRED	\$ -

Notes:

(1) Refer to IAC Sheet for IRB personnel cost calculator for daily rate

Additional notes:

If the conference is being held in conjunction with the ALPM then provide a % breakdown of shared expenses accordingly.
E.g. Conference = 6 hours and ALPM = 2 hours, then conference claim = 25% of shared expenses of one day.

Included:

- Notification of the meeting – advertising & distribution costs
- Travel, accommodation & meals for IAC Chairs
- Sitting fees for IAC Chairs
- Secretariat preparation costs (including IRB staff time)
- Venue & equipment hire

Excluded:

- Preparation by IRB office bearers

JUSTIFICATION / EXPLANATORY NOTES

[illegible]

HAL CONSULTATION

Note: This includes activities that are specifically providing advice to HAL on industry levy and VC programs, or facilitate general consultation with HAL

EXPENSES	Time ⁽¹⁾	Travel and Accommodation	Meeting Expenses ⁽²⁾	Total
IRB representative attendance at HAL Forums				\$ -
HAL CEO liaison with CEO				\$ -
HAL member consultation mtgs				\$ -
IRB CEO attendance at Across Industry Committee				\$ -
Prog WIP Mtgs with HAL				\$ -
Project Development with HAL staff				\$ -
Mtgs with Govt depts and service providers				\$ -
Other				\$ -
Total	\$0.00	\$0.00	\$0.00	\$0.00

ALLOCATION OF EXPENDITURE	Managed by IRB			Total
	VC (Matched)	R&D	Marketing	
Total				\$0.00

VC CONTRIBUTION REQUIRED	\$ -

Notes:

(1) Refer to IRB personnel time cost calculator on IAC sheet to calculate daily rates. Should not include costs for anyone covered under other HAL projects.

(2) Includes venue hire, teleconference, catering.

Additional notes:

<i>This includes activities that is specifically providing advice to HAL on, or aiding in the administration of, HAL industry levy programs</i>	
Included:	Excluded but may be funded by separate projects:
· Program work in progress meetings with HAL staff (preparation and involvement time)	· State and regional industry meetings with levy payers
· Project development with HAL staff	· Participation in non HAL related industry committees (eg PHA).
· Attendance at HAL Industry Forums (travel, accommodation and time)	· Secretarial/administrative support services to the IRB
· Attendance at IMC meetings (travel, accommodation and time)	· General industry liaison (processors, suppliers, etc)
· Attendance at Board to Board consultation meetings	· Meetings on regulatory issues e.g. climate change
· Meetings with Service Providers and Government Departments on HAL program related matters	
· Meetings with Government Ministers on HAL program related matters	Excluded – not funded by HAL:
	· Costs associated with the conducting of IRB Board business (travel & accommodation, sitting fees, insurances, honorariums, etc)
	· Meetings with Government Departments on non HAL program related matters.
	· PHA subscriptions and meetings costs are excluded. HAL will be working with PHA to coordinate HAL meeting locations and timings with PHA meetings so that wherever possible industries can offset travel and accommodation costs against fundable HAL activities.
	· Meetings with Government Ministers on non HAL program related matters.

Full Year Financial Reconciliation 2013/14 -

Funds Received	
- HAL	\$0
- Interest	\$0
Total	\$0

Expenditure	Budget (\$)	Actual (\$)	Variance (\$)	Comment
IAC				
Sitting fees (per meeting)	0		0	
IAC Member and secretariat travel and accommodation	0		0	
Presenters' travel and accommodation	0		0	
Venue hire	0		0	
Audio visual hire	0		0	
Catering	0		0	
Printing and dissemination of papers	0		0	
Secretariat support time	0		0	
Teleconference Calls	0		0	
Other	0		0	
Total	\$0	\$0	\$0	
Annual Levy Payers Meeting				
Notice of meeting	0		0	
Printing and dissemination of papers	0		0	
Dissemination of Annual Report	0		0	
IAC Chair and secretariat travel and accommodation	0		0	
IAC Chair sitting fees for attendance	0		0	
Venue hire	0		0	
Audio visual hire	0		0	
Catering	0		0	
Secretariat support time	0		0	
Other	0		0	
Total	\$0	\$0	\$0	
Consultation				
IRB representative attendance at HAL Forums	0		0	
HAL MD liaison with CEO	0		0	
HAL member consultation mtgs	0		0	
CEO attendance at Across Industry Committee	0		0	
Prog WIP Mtgs with HAL	0		0	
Project Development with HAL staff	0		0	
Mtgs with Govt depts and service providers	0		0	
Other	0		0	
Total	\$0	\$0	\$0	
Total Consultation Funding Expenditure	\$0	\$0	\$0	
Bank Charges and Other Miscellaneous Related Expenditure	\$			
Total Income / Expenditure	\$0	\$0	\$0	

Aggregate of IRB operating costs included in the above activities.(1)	\$

Signed: _____

Date: _____

Chair of the IRB

(1) Generally, the IRB operating costs that are included in the Consultation Funding Agreement can be calculated based on the daily rate of IRB staff time. The IRB personnel cost calculator (see IAC tab) includes an allocation for office rental, phone, computer, fax, printers, copiers, insurance (travel & professional indemnity). Add up these components and multiply by the number of days of staff time charged.

Australian Citrus

Strategic R&D Plan



2012–17

A plan to guide strategic
investment in citrus R&D

October 2012

Overview of the Plan

Vision

A profitable citrus industry that delights consumers with consistently high quality, great tasting products.

Mission

To efficiently deliver innovative and effective R&D solutions to support a profitable citrus industry.

Objectives & Key Strategy Areas

Objective 1: Develop and Maintain Market Opportunities		Objective 2: Increase Product Value		Objective 3: Improve Efficiency and Sustainability	
1.1 Market Access Ensuring open channels of international & domestic trade		2.1 Product Enhancement Locking in competitive advantages: taste, freshness & food safety		3.1 Production Efficiency & Innovation Finding new ways to increase production outputs and/or reduce costs	
1.2 Market Research & Analysis Understanding consumers, customers & competitors in order to develop new market opportunities		2.2 Product Development Developing new varieties & rootstocks in line with consumer preferences		3.2 Securing our Production Base Protecting our orchards from biosecurity & environmental threats	
Objective 4: Provide a Supportive Operating Environment					
4.1 Information & Communication Keeping our stakeholders informed through effective and timely communication and extension			4.2 Capacity & Capability Supporting industry operations through enhanced skills training, leadership and planning		

Introduction

Why a New Plan?

The current Citrus Industry Strategic Plan “*Creating our future: A national strategy for the citrus industry 2006 – 2011*” has guided activities over the past four years.

With the period of this plan completed and the significance of changes taking place in the Research and Development (R&D) environment, it is an opportune time for the citrus industry to develop a fresh Strategic R&D Plan.

Many challenging issues are facing the Australian citrus industry; and Australian horticulture more generally. There has never been a more important time to actively plan for the future.

What will the New Plan do?

This new plan has been developed to guide strategic investment of R&D levy expenditure managed through HAL over the next 5 years: 2012 - 2017.

During this period, Horticulture Australia Limited (HAL) is expected to oversee between \$25-30 million of investment in Citrus R&D. This will be funded through a combination of levy funds, voluntary contributions, and matched funding from the Federal Government.



How has the Plan been developed?

This R&D investment plan has considered the needs of the various citrus production regions and the full breadth of the supply chain.

Extensive industry consultation has been undertaken with stakeholders spanning the supply chain in order to ascertain needs and related actions required to move the industry forward.

Regional forums were held in each of the major citrus growing regions followed by a national R&D workshop, enabling participants at each of these events to comment on past, current and proposed R&D activities.

An overview of the plan was prepared and circulated to all industry contacts for comment. Following a second phase of consultation, the plan will be finalised for subsequent endorsement by the Citrus Australia Board and adoption by the Citrus Industry Advisory Committee (IAC).

How will the Plan be implemented?

This plan will be used by the Citrus IAC to guide R&D investment over the next five years. The plan will be reviewed by the IAC at least annually and will be used as the basis for developing Annual Investment Plans.

A detailed investment plan has been developed and will be continually reviewed by the Citrus IAC to further refine the investment program over the life of the plan.

Vision

A profitable citrus industry that delights consumers with consistently high quality, great tasting products.

Mission

To efficiently deliver innovative & effective R&D solutions to support a profitable citrus industry.

Objectives

Objective 1: Develop and maintain market opportunities	Objective 2: Increase product value	Objective 3: Improve efficiency and sustainability
Increase demand for Australian citrus by ensuring adequate access to domestic and export markets and by understanding consumers, customers and competitors in these markets.	Ensure the price of Australian citrus is maximised by improving our reputation as a reliable supplier of high quality citrus, capitalising on aspects of taste, colour, freshness and food safety.	Improve the productivity and international competitiveness of the Australian citrus industry and safeguard against potential threats.

Objective 4: Provide a supportive operating environment
Support industry development through enhancement of the operating environment, encompassing leadership and skills development, partnerships, communication, extension, planning and R&D capacity.



Objective 1:

Develop and Maintain Market Opportunities

Citrus represents Australia's largest fresh fruit export. With over 25% of Australia's citrus crop now being exported, maintaining and improving access and sales penetration in international markets is critical to the industry's future.

1.1 Market Access

Increasing global competition from lower cost producers and ongoing threats to existing access conditions place even greater importance on maintaining current market access and overcoming the complex array of trade barriers and restrictions faced by the industry. Neighbouring Asian countries are of particular focus, where Australia's close proximity provides an advantage over competitors. Improved export market access for Australian citrus also generates positive pricing pressure on domestic channels by reducing volume pressure in local markets.

1.2 Market Research & Analysis

The ability to identify and capitalise on new market opportunities requires an understanding of production trends, market requirements, customer needs and competitor activities. This understanding is developed through accessing reliable and timely information.

Objective 1: Develop and Maintain Market Opportunities

Key Strategy Areas	1.1 Market Access Ensuring open channels of international & domestic trade	1.2 Market Research & Analysis Understanding consumers, customers & competitors in order to develop new market opportunities
Strategies	1.1.1 Provide supporting data and resolve technical export market access issues 1.1.2 Facilitate new or improved quarantine protocols for key export markets 1.1.3 Provide supporting data and resolve technical domestic market access issues	1.2.1 Collect & analyse ongoing production and market information to support decision making 1.2.2 Identify, prioritise & develop new market opportunities 1.2.3 Drive citrus consumption through targeted consumer research, evaluation and value chain engagement
Outputs	➤ Scientific research to support improved quarantine and trade protocols for export and domestic markets ➤ Annually updated market access priority list	➤ Market information reports: market intelligence & scan data, market trends & consumer preferences, competitor analysis & market research reports ➤ Market development plans
Industry Outcomes	➤ Increased volume and value of Australian citrus exports ➤ Increased volume and value of domestic citrus sales ➤ Market access improvement (export and domestic) ➤ New & existing markets are developed for Australian citrus ➤ Co-investment by exporters and other industry stakeholders in market development initiatives ➤ Industry data is current and readily available in a range of formats	
KPIs	➤ Export market access: develop the South Korean market to increase export trade from currently negligible volumes to 10,000 tonnes annually with a FOB value of A\$15 million. ➤ Domestic market access: maintain postharvest dimethoate usage for fruit fly control and identify at least one alternate control treatment to ensure ongoing interstate movement of citrus. ➤ Market information: install a market intelligence reporting system which provides: 3-yearly reports of plantings, long-term forecasting & consumer trends; yearly reports of crop forecasts, end of season volumes & marketing campaign evaluation; and weekly reports of market dispatch & harvest rate.	
Target	➤ Increase the percentage of crop exported by 10% by 2016/17	



Objective 2: Increase Product Value

To become more internationally competitive it is imperative that in addition to maintaining and expanding existing and potential markets, the Australian citrus industry is able to supply a reliable, high quality product.

2.1 Product Enhancement:

Australia has a reputation for producing high quality citrus with the parameters of eating quality, food safety, taste, colour, and freshness being of greatest importance. Ensuring consistent quality is a constant challenge, but with improved quality comes the reward of increased value. This can be achieved through process improvement throughout the entire value chain, focusing on aspects of eating quality and food safety.

2.2 Product Development:

Access to superior varieties and rootstocks, selected to suit consumer preferences, can provide a multitude of benefits including extension of the marketing season, enhanced product quality and higher yields.

Objective 2: Increase Product Value

Key Strategy Areas	2.1 Product Enhancement Locking in competitive advantages: taste, freshness and food safety	2.2 Product Development Developing new varieties & rootstocks in line with consumer preferences
Strategies	2.1.1 Implement a national quality standards program to improve eating quality and convenience 2.1.2 Develop new products and practices which enhance eating quality 2.1.3 Find ways to improve pre-harvest quality and retain postharvest freshness and integrity of our products 2.1.4 Establish programs to support food safety across the supply chain methods	2.2.1 Import best available varieties & rootstocks from around the world 2.2.2 Support world-class quarantine services for importation of new varieties 2.2.3 Breed, evaluate & commercialise new, improved varieties and rootstocks specifically suited to Australian conditions 2.2.4 Provide independent information on new varieties for growers
Outputs	➤ Enhanced and widely adopted citrus quality standards ➤ Taste enhancing products and practices ➤ Postharvest treatments that maintain freshness and meet customer requirements ➤ Food safety programs	➤ Commercially available new varieties & rootstocks suited to Australian conditions and consumer preferences ➤ Independent information on new varieties provided to growers
Industry Outcomes	➤ A strong international & domestic quality reputation for Australian grown citrus ➤ Proven industry commitment to the Australian Citrus Quality Standards ➤ Increased volume and value of Australian citrus sales (export and domestic) ➤ The industry effectively responds to any food safety issues that arise	
KPIs	➤ Quality improvement: achieve consistent 95% compliance with national eating quality standards by 2017. ➤ Food safety: establish a national residue testing program that is targeted to specific markets and recognised by relevant governments. ➤ New products: deliver to industry 10 new high-health varieties that have been independently evaluated for production and market potential.	
Target	➤ Increase local (farm gate) value of production per hectare by 10% by 2016/17	



Objective 3: Improve Efficiency and Sustainability

3.1 Production Efficiency & Innovation

Research that supports reduced input costs through improved efficiency is essential in countering increasing levels of global competition. Unpredictable variation in seasonal crop production caused by biennial bearing is of particular concern, leading to variability in production levels and fruit size. This causes considerable strain on many aspects of the citrus value chain including citrus packing, processing and marketing. Overcoming this variability is critical to supplying markets with consistently high quality fruit.

3.2 Securing our Production Base

Despite Australia's rigorous quarantine system, a variety of exotic pests still pose a threat to the Australian citrus industry. Climate change and increased climate variability will also present a range of future challenges for the industry. It will be critical to seek means for reducing the environmental impact from business operations and ensure efficient and sustainable management of natural resources including water and soils. Adoption of Integrated Pest Management (IPM) strategies will become increasingly essential. Safeguarding the industry against these and other risks requires ongoing investment in both planning and preparedness.

Objective 3: Improve Efficiency and Sustainability

Key Strategy Areas	3.1 Production Efficiency & Innovation Finding new ways to increase production outputs and/or reduce costs	3.2 Securing our Production Base Protecting our orchards from biosecurity & environmental threats
Strategies	3.1.1 Investigate cost effective means for increasing sustainable yields of marketable fruit 3.1.2 Explore, evaluate and promote lower cost or more productive production techniques	3.2.1 Strengthen industry planning and preparedness in relation to biosecurity and other risks, and facilitate awareness of new invasive pests and diseases 3.2.2 Support maintenance of clean planting material and encourage plantings that are based on high-health, genetically superior nursery trees 3.2.3 Support improved pest management strategies 3.2.4 Investigate sustainable use of water, soils and other natural resources
Outputs	➤ Citrus production technology gap analysis and cost benefit analysis ➤ Effective crop regulation practices ➤ Lower cost production techniques ➤ Precision application methodology for water, nutrition and pesticides/fungicides	➤ Current and adequately resourced biosecurity and risk management plans ➤ Training and simulation activities undertaken to enhance risk response preparedness
Industry Outcomes	➤ Increased marketable yield per hectare and reduced cost of production per kilogram ➤ Improved supply chain efficiency ➤ Reduced environmental impact from citrus production ➤ Effective industry response to biosecurity and other crisis issues	
KPI's	➤ Crop regulation: deliver a predictive cropping intensity model which allows growers to better regulate cropping cycles to meet market demand. ➤ Biosecurity: develop and implement a national biosecurity program (including a national approach to fruit fly) which increases awareness, surveillance and capability as demonstrated via an outbreak simulation exercise.	
Target	➤ Increase average yield per hectare by 20% by 2016/17	



Objective 4: Provide a Supportive Operating Environment

4.1 Information & Communication

R&D can only be effective with high levels of adoption. It is important that effective extension mechanisms are in place to ensure that information is transferred in a timely and meaningful way, thereby maximising opportunity for rapid adoption. Communication and collaboration between all industry stakeholders need to be encouraged, in addition to the continued need for streamlining of industry communications.

4.2 Capacity & Capability

The Australian citrus industry has a recognised lack of structured leadership and skills development, with ongoing difficulties in attracting and retaining skilled staff. This requires establishment of a proactive capacity building program. The limited availability of R&D funding is a further issue requiring serious consideration.

Objective 4: Provide a Supportive Operating Environment

Key Strategy Areas	4.1 Information & Communication Keeping our stakeholders informed through effective and timely communication and extension	4.2 Capacity & Capability Supporting industry operations through enhanced skills, leadership and planning
Strategies	4.1.1 Facilitate effective communication between all industry stakeholders including growers, supply chain members, service providers, government and community 4.1.2 Undertake and support effective extension activities to support adoption of best practice technologies	4.2.1 Enhance capacity to support current & future industry needs, focusing on enhanced leadership capacity and improved skills development across the citrus supply chain 4.2.2 Develop & maintain collaborative partnerships to support citrus industry development and analyse industry data to provide a sound basis for planning and communication to stakeholders 4.2.3 Ensure an effective advisory process that maintains regular and meaningful industry feedback for each key program and region 4.2.4 Ensure implementation of the Strategic R&D Plan
Outputs	➤ Dynamic national website, electronic media, streamlined publications, regional & national forums, and a national conference ➤ Regular effectiveness survey of information/communications	➤ Scholarships, training programs and other initiatives supporting leadership & skills development ➤ Transparent and representative advisory committee structure ➤ An Annual Investment Plan that is well-aligned to the Strategic R&D Plan ➤ Strategic R&D Plan Implementation Review Report
Industry Outcomes	➤ Industry stakeholder satisfaction with information/communications program ➤ Industry capacity is enhanced through increased skills development ➤ Demonstrated return on levy funds invested in research & development	
KPI's	➤ R&D investment: demonstrate an increase in satisfaction with levy investment (including industry engagement, priority setting, process governance & outcomes) by surveying levy payers at the start and end of plan. ➤ R&D uptake: demonstrate an increased rate of adoption of R&D outcomes by surveying industry stakeholders at the start and end of plan.	



Australian Citrus R&D Action Plan

This document summarises key actions and investments required to implement the Australian Citrus Strategic R&D Plan. Given the dynamic nature of the industry and its operating environment, this document is intended to be reviewed and updated on an ongoing basis.

Funding for these activities will primarily be sourced from the National Citrus R&D Levy, together with matched funding from the Federal Government, administered by Horticulture Australia Limited (HAL).

The plan has been underpinned by an analytical business case, identifying priority areas where investment is most likely to result in the greatest return.

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Objective 1: Develop and Maintain Market Opportunities

	Strategy	Actions
1.1 Market Access	1.1.1 Provide supporting data and resolve technical export market access issues	- Develop a network of technical experts to drive development of novel systems approaches and disinfestation methods for key pests for sensitive markets (eg. Fullers rose weevil, red scale, mealy bugs, light brown apple moth, citrus black spot) - Resolve fruit fly protocol issues: in-transit cold treatment, varietal anomalies, additional fruit fly species
	1.1.2 Facilitate new or improved quarantine protocols for key export markets	- Annually review export market access priorities based on business case analysis - Submit new protocol priorities and supporting analysis to OHMA - Engage with relevant government authorities on key market access projects, including Biosecurity Australia, the Australian Quarantine Inspection Service (AQIS), the Australian Department of Agriculture, Fisheries and Forestry (DAFF), the Australian Department of Foreign Affairs and Trade (DFAT)
	1.1.3 Provide supporting data and resolve technical domestic market access issues	- Conduct initial stocktake and prioritisation of domestic market access issues - Annually review domestic market access priorities based on business case analysis - Engage with state government authorities on strategies for managing key pests & diseases affecting inter-state fruit movement - Investigate and support research on alternative methods and approaches for fruit fly and citrus black spot
1.2 Market Research & Analysis	1.2.1 Collect & analyse ongoing production and market information to support decision making	- Ensure ongoing collection and analysis of information relating to: - National plantings database updated every 3 years - Regional and national crop forecasts (seasonal and long-term) - Weekly market dispatch reports generated through InfoCitrus - Export and import data - International competitor performance - Consumption trends and consumer preferences
	1.2.2 Identify, prioritise & develop new market opportunities	- Analyse market intelligence data to highlight trends/opportunities in current and future markets - Determine market development directions and value chain strategies based on ongoing market analysis - Coordinate trade missions to / from priority new and existing markets - Engage with Australian and overseas agencies regarding trade conditions in priority markets - Maintain a watching brief on tariff arrangements and identify information requirements to support respective negotiations - Develop a “one stop shop” for export market information
	1.2.3 Drive citrus consumption through targeted consumer research, evaluation and value chain engagement	- Ensure consumer and market information drives citrus marketing strategies - Strengthen whole of value chain consultation - Review and implement best practice/innovative fresh produce marketing strategies - Ensure regular evaluation of marketing strategy and programs

Objective 2: Increase Product Value

	Strategy	Actions
2.1 Product Enhancement	2.1.1 Implement a national quality standards program to improve eating quality and convenience	- Review and undertake sensory evaluation research to refine consumer eating quality preferences - Annually review industry quality standards based on consumer preference analysis - Engage full value chain in quality improvement through communication, training and monitoring - Investigate all options for achieving quality standards compliance
	2.1.2 Develop new products and practices which enhance eating quality	- Ensure that product development activities are focused on eating quality improvement - Investigate and evaluate orchard practices which enhance eating quality - Support research and extension of grading technology to differentiate superior eating quality product
	2.1.3 Find ways to improve pre-harvest quality and retain postharvest freshness and integrity of our products	- Continued support and enhancement of a world-class post-harvest program - Continually search for new orchard and postharvest technologies/practices for maintaining product integrity - Investigate fruit waxes and coatings which enhance freshness and shelf-life of packed product
	2.1.4 Establish programs to support food safety across the supply chain	- Investigate options for establishing a national government-recognised residue testing system customised to suit current export and domestic market requirements - Continually inform industry of residue compliance requirements for export and domestic markets - Undertake a strategic agrichemical review process (SARP) and initiate consequent recommendations to ensure a pro-active approach to agrichemical management
2.2 Product Development	2.2.1 Import best available varieties & rootstocks from around the world	- Maintain surveillance of international variety development through overseas study trips and networks - Enable industry access to promising public-domain varieties and rootstocks
	2.2.2 Support world-class quarantine services for importation of new varieties	- Ongoing engagement with AQIS to ensure that quarantine facilities & methodologies are technically appropriate for citrus budwood & seed importation - Establish communication network with variety importers/commercialisers to ensure smooth passage of material through quarantine
	2.2.3 Breed, evaluate & commercialise new, improved varieties and rootstocks specifically suited to Australian conditions	- Maintain access to CSIRO breeding material for evaluation - Support ongoing breeding and evaluation programs that are focused on key market preferences (eg. eating quality, early season, late season, seedless easy-peel and pigmented varieties)
	2.2.4 Provide independent information on new varieties for growers	- Maintain and encourage commercialiser involvement in an impartial, national evaluation program with sites located in each key growing region - Organise regular forums to facilitate communication between growers and commercialisers - Maintain updated variety fact sheets

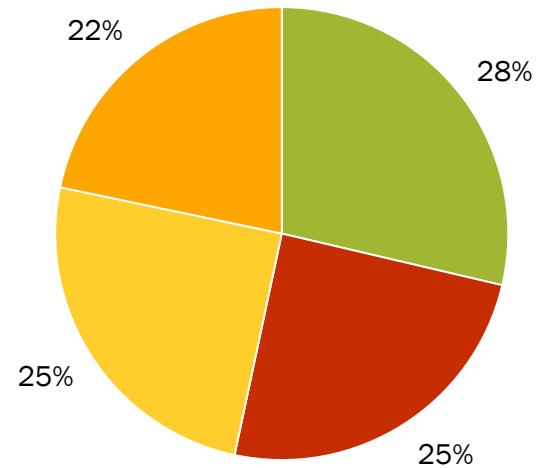
Objective 3: Improve Efficiency and Sustainability

	Strategy	Actions
3.1 Production Efficiency & Innovation	3.1.1 Investigate cost effective means for increasing sustainable yields of marketable fruit	- Analyse cost benefits of production practices - Conduct gap analysis of citrus production technology research - Research, evaluate and promote production practices that ensure more even cropping and marketable fruit size and quality
	3.1.2 Explore, evaluate and promote lower cost or more productive production techniques	- Support research into more labour efficient production practices (eg. mechanical harvesting) - Investigate and promote new labour access programs (eg Pacific Seasonal Workers Program)
3.2 Securing our Production Base	3.2.1 Strengthen industry planning and preparedness in relation to biosecurity and other risks, and facilitate awareness of new invasive pests and diseases	- Develop and implement a national biosecurity awareness program: - Facilitate awareness of new invasive pests and diseases through regular, coordinated communications such as fact sheets - Ensure biosecurity and other risk management plans are effective and up-to-date, supported by adequate education, training, surveillance and resourcing: - Establish a network of biosecurity contacts in each state/region - Conduct outbreak simulation exercises to test response readiness - Work with Plant Health Australia (PHA) to ensure appropriate arrangements in place for owner reimbursement costs - Provide regular biosecurity training activities, including Emergency Plant Pest Response Deed (EPPRD) training for key industry representatives - Provide technical data and support surveillance for exotic pests and for endemic pests affecting market access
	3.2.2 Support maintenance of clean planting material and encourage plantings based on high-health, genetically superior nursery trees	- Provide ongoing support for Auscitrus activities - Promote take-up of Auscitrus seed and budwood through nursery networks and workshops - Support indexing for the Auscitrus budwood scheme that is reliable and cost effective and keeps abreast of new pathogens and methodologies
	3.2.3 Support improved pest management strategies	- Ensure adequate pathology and entomology resources - Establish a network of pest management technicians & researchers - Engage in national and regional projects for managing fruit flies and other priority orchard pests and diseases - Support development of Integrated Pest Management (IPM) strategies
	3.2.4 Investigate sustainable use of water, soils and other natural resources	- Assist industry to demonstrate and improve its environmental credentials - Support research and extension projects on water efficiency and fertigation - Extended lifecycle studies to give reliable carbon and water use data - Explore and report on clean energy opportunities including carbon sequestration and emissions in citrus production & supply chain

Objective 4: Provide a Supportive Operating Environment

	Strategy	Actions
4.1 Information & Communication	4.1.1 Facilitate effective communication between all industry stakeholders including growers, supply chain members, service providers, government and community	- Develop and implement an enhanced communications program incorporating regular surveys to gauge effectiveness and improvement strategies - Encourage information sharing and value chain interaction through a range of activities including: regional and national events, magazine, website, newsletter, workshops, field days - Provide timely industry data and supporting analysis to support decision making across the citrus value chain - Disseminate up-to-date production and market-related information through a variety of media
	4.1.2 Undertake and support effective extension activities to support adoption of best practice technologies	- Establish and maintain a national extension network and ensure linkage incorporated into future research activities - Transfer of technical information supported by an extension program encompassing field days, workshops, training sessions and electronic access to research reports, extensions publications and fact sheets. - Investigate ways to better facilitate dissemination of research funded by HAL and external agencies
4.2 Capacity & Capability	4.2.1 Enhance capacity to support current & future industry needs, focusing on enhanced leadership capacity and improved skills development across the citrus supply chain	- Develop and implement a national leadership program for the Australian citrus industry - Encourage involvement from across the citrus value chain in recognised training courses, international study trips and conferences - Promote external training programs and related initiatives that focus on leadership and skills development
	4.2.2 Develop & maintain collaborative partnerships to support citrus industry development and analyse industry data to provide a sound basis for planning and communication to stakeholders	- Identify existing and potential strategic partners and where beneficial, develop a plan for enhanced engagement - Engage with research agencies through the National Horticultural Research Network (NHRN) - Enhance collaboration within the citrus industry, across the horticultural industry, broader agricultural sector and international linkages
	4.2.3 Ensure effective advisory process that maintains regular and meaningful industry feedback for each key program and region	- Regularly review IAC and advisory committee structures and membership, ensuring that skill requirements are met, and responsibilities are aligned to the Strategic R&D Plan - Develop and implement a structured consultation process, incorporating regular regional engagement - Establish and regularly review reference groups to support advisory process for key issue areas: orchard production, pest & disease control, postharvest, juice production, nursery production and biosecurity:
	4.2.4 Ensure implementation of the Strategic R&D Plan	- Develop and implement effective R&D projects in an integrated program approach that is aligned to the Strategic R&D Plan - Ensure adequate resourcing is available to support implementation of the Strategic R&D Plan including: - Appropriate levy structures/rates - Appointment of a Market Access Manager, Biosecurity Manager and Value Chain Co-ordinators in each key region - Development of future RD&E capacity - Annually review implementation of the Strategic R&D Plan

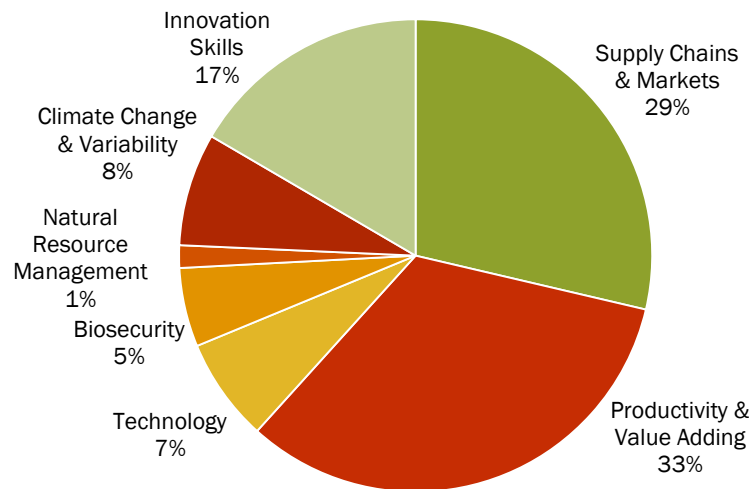
Investment Analysis



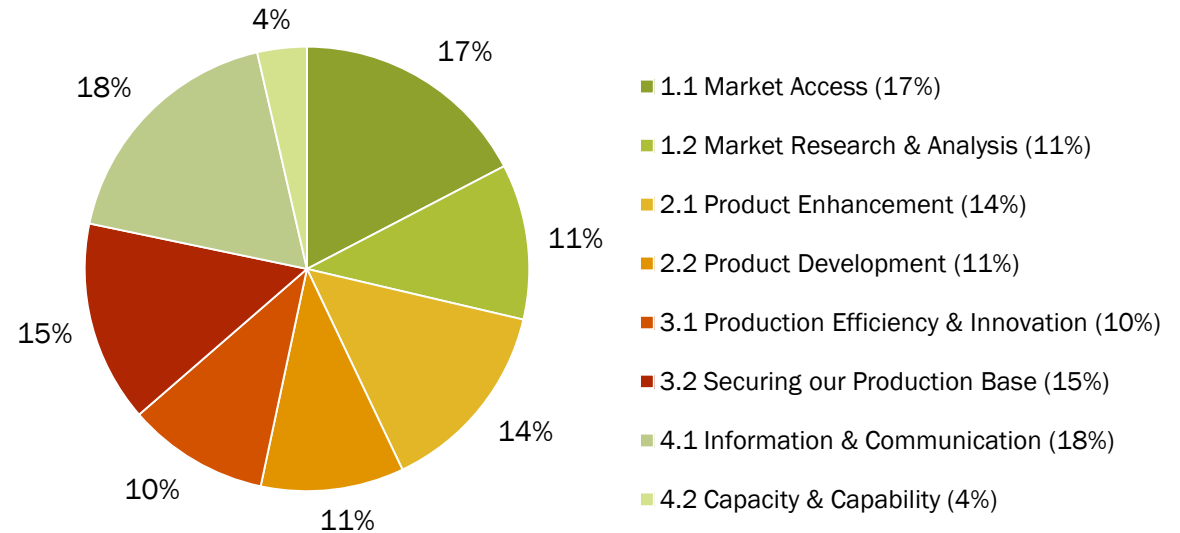
R&D Investment by Objective

- Obj 1 - Develop and maintain market opportunities
- Obj 2 - Increase product value
- Obj 3 - Improve efficiency & sustainability
- Obj 4 - Provide a supportive environment

R&D Investment by Government Priorities



R&D Investment by Key Strategy Area



For further information relating to the Australian Citrus Industry R&D Program visit:

Citrus Australia website: www.citrusaustralia.com.au

Horticulture Australia website: www.horticulture.com.au



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**SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
REFERENCES COMMITTEE**

Inquiry into the review of the citrus industry in Australia

Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013 and Thursday, 4 July 2013

Mildura Fruit Company (MFC)

Written Questions on Notice - Senator Ruston

Question 1	Minimum juice content	In its submission and in evidence (p34, Mildura 4 July 2013), MFC proposed the Australian Government mandate a requirement that orange juice manufactured in Australia have a minimum content of Australian-grown produce (30% according to the submission). Can MFC provide more detail about this proposal, specifically with regard to the statement in evidence "...that if the government mandated a percentage that would then give the Australian grower some hope that they can move their fruit at a reasonable price."

**SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
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Inquiry into the review of the citrus industry in Australia

Written Questions Taken on Notice from Public Hearings on Wednesday, 3 July 2013 and Thursday, 4 July 2013

Riverina Biosecurity Committee (RBC)

Written Questions on Notice - Senator Ruston

Question 1	Structure	Mr Phillip Blacker asked a number of questions during the hearing in Griffith that are best answered by the Riverina Biosecurity Committee (RBC). These questions are as follows: • Why is citrus the only financial contributor to the RBC? • Who actually instigated the RBC? • Was the RBC a legal entity when the funds were given to it? • Who does the RBC answer to? • Who are the RBC's voting members? • As of last week, and I am not sure, the RBC's constitution still has not been ratified. Is this correct? • Who put the current chairman [of the RBC] in the position prior to April? • Does Mr Davidson, who is also here today, have a conflict as an employee of DPI, an industry service provider, a Citrus Australia Ltd member and past chair, Leeton Shire councillor as well as a grower? • Do NSW DPI and Citrus Australia Ltd have conflicts as they now manage the pest-free area funds that come from Horticulture Australia Ltd? NSW DPI are using our funds on a program which has failed under their leadership. • How can NSW DPI help project funds for a pest-free area accreditation when DPI are actually disbanding the fruit fly exclusion zone? They are removing penalty notices from road signage. Within the next three years you will see no evidence of fruit fly area freedom.
Question 2	Business plan	Does the RBC have a business plan? Was this a requirement of the NSW DPI in the allocation of funds to the RBC?

**SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT
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Question 2	Business plan	Does the RBC have a business plan? Was this a requirement of the NSW DPI in the allocation of funds to the RBC?

Answers:

Question 1

- 1 Citrus has always carried the bulk of the financial contribution toward the control of Qld fruit fly. Riverina Biosecurity Incorporated (RBI) has had contributions from Leeton Citrus Growers Inc.(LCGI) of \$5000.00, Griffith Citrus Growers Inc.(GCGI) of \$5000.00 and the MIA Prune Association of \$500.00. At a meeting called by the Member for Murrumbidgee, Adrian Piccoli last October in Griffith with 70 people in attendance it was decided that the surplus money that was available from the wind up of Riverina Citrus (RC) would best be used in the control of fruit fly. The State Government announced that RBI would receive approximately \$595,000, LCGI, \$127,000 and GCGI, \$127,000. To date those organisations have received half of that money. NSW DPI have also contributed to RBI. They have had brochures printed for letter drops to houses, paid for a television awareness campaign and have gifted to RBI 3 mules and spray equipment to the value of around \$50,000. Leeton and Griffith Shires have funds set aside for fruit fly. The other three shires of Carrathool, Narrandera and Murrumbidgee will do what they can to assist RBI.
- 2 The concept of Riverina Biosecurity Committee was initiated by RC in 2011 and when RC folded, Citrus Australia (CA) assisted the Riverina region to continue with the concept and RBI was formed.
- 3 Riverina Biosecurity was incorporated through NSW Fair Trading. Inc No. INC1200173 and issued on 23rd October 2012.
- 4 RBI is made up from members from four citrus groups(LCGI, GCGI, Riverina Citrus Growers Inc,(RCGI) and CA) Prunes, Wine Grape marketing Board, (WGMB) Stone Fruit, NSW DPI and any other interested groups that were identified in the Business Case. RBI with these members make decisions at monthly meetings and they are acted on. RBI is answerable to its members.
- 5 The members listed above are the voting members. A set of By-laws are being developed by a solicitor to strengthen the Model constitution that we operate under.
- 6 As stated RBI is an Incorporated organisation and has a Constitution to abide by.
- 7 Mr Peter Davidson is the chairman of RBI. He was elected at a monthly meeting held at the conference room , NSW DPI Office at Murray Rd Griffith on Wednesday 20th June 2012. The members that attended that meeting voted for a Chairperson.
- 8 Advice from several people was sought to determine if Mr Davidson had a conflict of interest and all responded no. A solicitor was consulted and he arrived at the same conclusion. The members of RBI were asked and they didn't see a conflict of interest.
- 9 I don't quite understand this question. We are not a Pest Free Area(PFA) any more, we are now classified as low pest prevalence so I don't believe there is any conflict of interests. RC had a VC project with Horticulture Australia(HAL) to deal with fruit fly related issues and this was terminated when RC ceased to exist. CA ,RBI,HAL,NSW DPI and the Citrus advisory committee all worked together to come up with a project to have a fruit fly project officer in place for three days a week for a three year period. The left over money from the RC project with HAL(\$80,000?) was then used in the RBI project.
- 10 Once again we are not a PFA and the signage will most likely removed as they are not enforceable under legislation.

Question 2

Yes RBI has a business plan which was commissioned in July 2012 (attached). No this was not a requirement of NSW DPI in the allocation of funds to RBI(I presume Mr Blacker means the money from RC when it is liquidated)

Business Case

For a Grower-Driven Fruit Fly Control Campaign



Photo courtesy of NSW Department of Primary Industries

www.dpi.nsw.gov.au/agriculture/pests-weeds/insects/images/images-and-extras/ff-onfruit.jpg

Prepared by

Peter Davidson & Kate Davidson

For

Riverina Biosecurity Committee

July 2012

Contents

1. Executive Summary	3
2. Introduction.....	4
3. Survey of Fruit Fly Susceptible Crops	7
4. Operations Model for Crop Control	10
5. Costing the Operation	11
6. Mechanisms for Total Crop Coverage	17
7. Communications Strategy	19
8. Recommendations for future of the control campaign	22

1. Executive Summary

The business plan for a Grower-Driven Fruit Fly Control Campaign aims to identify all commercial fruit fly susceptible crops in the Riverina, and from this, develop a sustainable crop control program with a commitment from all stakeholders. The report also acknowledges NSW DPI and local council programs to assist the control of fruit fly susceptible fruit trees grown by householders.

A survey of fruit fly susceptible crops was undertaken to help ascertain for each crop, the most important times of year a bait spray program must be carried out to prevent a possible outbreak of fruit fly. It must be recognised that susceptibility periods will only ever be a guide due to seasonal fluctuations.

When considering the operations model for crop control, a well-planned and well-coordinated grower-driven bait spray program will determine the success of entire regional control program. The bait spray program is the linchpin of the whole operation. From this, other control measures would then be introduced.

The plan establishes that growers will bear the majority of the cost of a bait spray program. An exhaustive audit of estimated costs of the program for each commercial crop has been undertaken in Section 5 of the plan. The maximum cost of a bait spray program in the Riverina is estimated to cost approximately \$3.75 million (detailed figures in Section 5). NSW DPI and local councils will also assist in a total control program by implementing their own bait spraying programs for towns and backyards. The plan also makes a strong recommendation that a project officer be employed in order for the program to be successful and sustainable.

Important mechanisms for total crop coverage have been identified in Section 6. In order for maximum crop coverage to be achieved a complete review of the NSW Government “Plant Diseases (Treatment and Eradication of Queensland Fruit Fly, Riverina) Order 2011” needs to be undertaken. Again, it is emphasised that the crucial method of crop control would be a rigorous and ongoing grower-driven bait spray program.

The communication strategy discussed in Section 7 will be a fundamental aspect of the total crop control campaign. The message of fruit fly control must be unified and embedded in grower and householder culture.

Twelve stakeholders have been identified to guarantee successful implementation of a control program. Recommendations have been made for each stakeholder, defining their roles and responsibilities which will ensure a cohesive approach to a total control campaign.

2. Introduction

Historically, of all the horticultural commodity groups, the citrus industry has shouldered the financial burden of the control of fruit fly in the Riverina¹. It must also be acknowledged that NSW Department of Primary Industries (DPI) has been a major contributor in the fight against fruit fly. Midway through 2011, Riverina Citrus (RC) instigated the establishment of the Riverina Biosecurity Committee (RBC). RC recognised that the fruit fly problem was one that needed to be addressed by the community as a whole. After the demise of RC in March 2012, Citrus Australia Ltd stepped-in to progress the intentions of the RBC. The RBC is currently represented by the region's commodity groups² and NSW DPI. It is crucial that Local Councils be involved in the process.

When there is an outbreak of Queensland fruit fly, the costs can arguably be measured in the millions of dollars through extra treatment expenses and lost trade opportunities. Fruit fly-free areas will derive benefits such as improved market access, reduced market access cost, enhanced profitability and cost reductions, and a reduction in production losses in fruit fly susceptible crops.³ The current outbreak of fruit fly in the Riverina will undoubtedly add extra costs to growers budgets. This will be in the form of reactive spraying, extra fruit packing costs related to market access protocols and, most seriously, the possible rejection of growers' crops as marketable products.

After the record numbers of fruit fly trappings of 28,000 flies in 2010/11 and 25,000 flies in 2011/12⁴, it is known that a routine bait spray program needs to be implemented to achieve maximum coverage of horticultural crops⁵ and backyards. Growers need to take ownership of the problem by acknowledging that there is in-fact, a problem and then be willing to address the problem by consistently adhering to a bait spray program. Previously, the attitude of many Riverina growers to fruit fly outbreaks has been reactive; however, in light of the frequent fruit fly outbreaks in recent years, they need to accept that the luxury of area freedom status is no longer a guarantee. Growers will need to adopt a much more proactive approach to controlling fruit fly, similar to that of the citrus growers in Queensland. In such an endemic environment growers are baiting their farms for the control of fruit fly on a weekly basis. This "Queensland Culture" is essential to maintaining growers' livelihood.

There are approximately 30,000 hectares of horticultural crops in the Riverina region. If a spray program is to cover this area, a network of people involving individual growers, groups of growers or contractors

¹ Riverina refers to the Local Government areas of Carrathool, Griffith, Leeton, Murrumbidgee, Narrandera

² For the purpose of this report, commodity groups will refer to apples, avocados, cherries, citrus, grapes, prunes, stonefruit, walnuts regardless of whether there is formal representing organisation or not

³ National Fruit Fly Strategy Implementation Action Plan, p22, April 2010

⁴ Figures obtained from NSW Department of Primary Industries

⁵ Horticultural crops refers to the commercial crops of the Riverina: Apples, Avocados, Cherries, Citrus, Figs, Grapes, Prunes, Stonefruit & Walnuts

needs to be well coordinated to ensure such a program can be delivered. It has to be agreed that a Riverina-wide approach will be highly challenging and time consuming, but entirely necessary. For example, a contractual bait spraying service provided by a local citrus packhouse takes one person one week to spray 500 hectares.

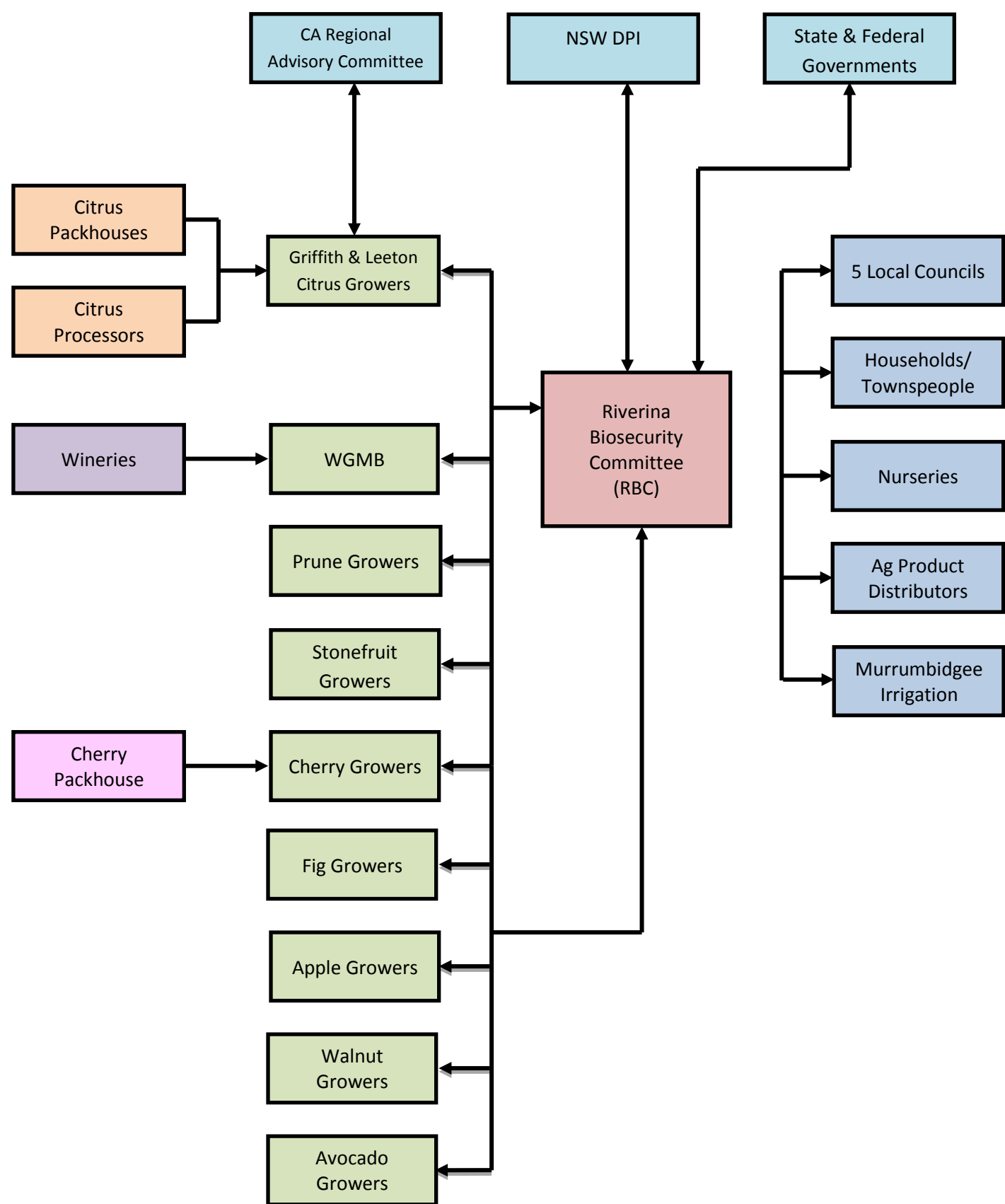
The information supplied by NSW DPI on fly trapping needs to be analysed and distributed quickly so that growers are able to react to any “hotspots” or fly movement within districts. Formation of a database of all growers which includes contact information such as email addresses and mobile phone numbers for immediate broadcast of important fruit fly movement, is essential.

The management of fruit flies⁶ in the Riverina is undertaken by a broad range of stakeholders.

Figure 1 illustrates the relationships between relevant stakeholders to help understand how a fruit fly control program would be implemented. Ultimately, it will be the individual grower in each commodity group who will shoulder the financial burden of a crop control program; however, appropriate and timely assistance from the RBC, grower organisations, local councils and NSW DPI will enable the control program to be sustainable. To deliver a cohesive control program, an attitudinal and behavioural change by growers in their approach fruit fly management in the Riverina, is crucial. Only after this is achieved, will other methods be able to successfully compliment an established crop control program.

⁶ For the purpose of this report, the term fruit fly will refer to Queensland fruit fly

Figure 1 – Relationship between Key Stakeholders and the Riverina Biosecurity Committee for the Management of Fruit fly.



3. Survey of Fruit Fly Susceptible Crops

A survey of all commercial horticultural crops in the Riverina was undertaken⁷. Information was obtained from NSW DPI, local grower organisations and individual growers. When assessing the susceptibility of crops, the following points need to be considered:

- Farms with garden orchards need to be recognised and targeted.
- Once the temperature in an area rises above 17-18°C, and remains above this temperature for extended periods, fruit fly activity will increase.
- Susceptibility periods are only a guide as seasonal fluctuations (early or late seasons) will affect the onset, maturation and cessation of crop harvest, e.g. in a late season fruit will hang for longer. It is a requirement that this fruit be picked and removed before the winter months to prevent old fruit becoming an initial host for the following spring.
- A concerted bait spray program must commence early in the season when fruit fly numbers are low to abate numbers so the fruit fly breeding population is unable to establish itself.
- If numbers of fruit fly in a particular crop are found to be extremely high, consideration must be made to apply a cover spray to drastically decrease fly numbers before entering into a bait spray program.
- Grapefruit, mandarins and lemons are more fruit fly susceptible than oranges. A directive must be made by RBC that upon completion of these crops, all fruit must be removed.
- Climate will determine susceptibility, i.e. less fruit fly activity in winter months
- Stonefruit includes Apricots, Nectarines, Peaches
- Walnuts are a host. Fruit fly larvae have been found between the green outer casing and the nut.

⁷ The term commercial will refer to any Riverina horticulture crop over 1 hectare

Table 1.2 - Home Garden Fruit Fly Susceptible Host Fruit

Fruit	Period of Susceptibility
Apple	February - July
Apricot	October - January
Avocado	June - February
Blackberry	October - November
Blueberry	November - December
Capsicum	September - June
Cherry	September - December
Chilli	September - June
Citron	August - December
Cumquat	July - June
Eggplant	September - June
Feijoa	November - May
Fig	January - May
Grapes	January - April
Grapefruit	July - June
Guava	November - May
Kiwifruit	January - April
Lemons	July - June
Lime	July - June
Loquat	September - November
Mandarin	March - November
Mango	January - April
Mulberry	October - November
Nashi	January - April
Nectarine	November - February
Orange	July - June
Passionfruit	September - May
Peach	October - April
Peacharine	November - February
Pear	February - April
Persimmon	March - June
Plum	November - April
Plumcot	November - December
Pomegranate	October - August
Prickly Pear	December - August
Pummelo	July - June
Quince	April - June
Shaddock	July - June
Strawberry	September - May
Tangelo	June - October
Tomato	December - May
Walnut	December - February

Information in tables 1.1 and 1.2 obtained from NSW DPI.

4. Operations Model for Crop Control

The scope of the operations model will include not only an established and routine bait spraying program performed by individual growers, but also a wider fruit fly control campaign that incorporates awareness, prevention, detection, management and communication strategies undertaken by the other relevant stakeholders. At this regional level, the operations model will be driven by RBC and will involve NSW DPI, the five local councils, commodity groups, and the wider public. An effective control campaign would also incorporate the use of homemade pots, fruit fly lures, and where necessary cover sprays.

Individual Growers

The primary focus will be on the individual grower being responsible for bait spraying their own farm. RBC will need to develop a standardised bait spray program timetable indicating ideal spraying intervals. This can form an integral part of the growers' spray diaries.

Groups of Growers

If the individual grower is unable to do this, it is then suggested they work with a neighbour or several neighbours to coordinate and implement a spraying program. The bait spray timetable would be adapted to incorporate ideal spray intervals for each property. The shed information days to be held by RBC in August 2012 will be a vehicle for identifying groups of growers who are willing to coordinate their spray program and assist each other.

Contractors

If the above is not feasible then employment of a contractor can be arranged. This would then determine how the area as a whole is to be divided into sub-districts, for example, Corbie Hill, Wamoon, Tharbogang, Lake Wyangan etc. A network of contractors needs to be established with the assistance of RBC, citrus packhouses, processors and commodity groups. Expressions of interest through the RBC and their members would be the recommended method of sourcing contractors.

Packhouses, Processors, Wineries & Commodity Groups

If each of these organisations were able to make arrangements to organise a regular contractor, they will greatly contribute to easing the fruit fly problem through the regular bait spraying method of crop control. For instance, a contractor being managed or employed by a packhouse will be given a spray schedule to spray the farms that supply the packhouse on a regular basis. These groups are one of the primary drivers in compliance to a fruit fly control program by implementing a requirement that produce will not be accepted unless a rigorous spray program has been adhered to.

5. Costing the Operation

In the current economic climate, it must be acknowledged that any new investment or funding for a regional fruit fly control program will be very limited. Individual growers will need to fund the cost of the bait spraying program themselves.

Vineyards pose the greatest difficulty in determining the cost of a bait spray application per hectare because the recommended spray coverage for a vineyard is to spray every sixth headpost, and the number of headposts per hectare differs on every vineyard. After consultation with the WGMB an average amount of headposts per hectare was calculated after sampling various properties within the following three size categories; Small (<20 ha), Medium (20-100 ha) and Large (>100 ha). Refer to Table 2.3.

It would also be recommended that a 4-week autumn foliage bait spray program be carried out, covering the entire 22,000 hectares of vineyards (not solely headposts). For a cost estimate, refer to Table 2.4.

- The figures below are approximate and are based on the average retail price of Hymal[®] and Yeast Protein:
 - Hymal[®]: 20L @ \$384 (incl GST)
 - Yeast Protein: 20L @ \$385 (incl GST)
- Using the rate of 2L Yeast and 875ml Hymal to 100L of water the bait mixture would cost: \$55.30 per 100L (approximately).

The figures above have been used to formulate Table 2.1.

Table 2.1 – Cost of Bait Spray per Hectare for Commercial Crops

Crop	Spacings (metres)	Trees/Ha	Spray Pattern	Application Rate	Approx Litres/Ha	Cost Spray/Ha
Apples	6m x 4m	420	every 2nd row, every 4th tree	100ml	5.3L	\$2.93
Avocados	6m x 6m	272	every 2nd row, every 2nd tree	100ml	6.9L	\$3.82
Cherries	6m x 4m	420	every 2nd row, every 4th tree	100ml	5.3L	\$2.93
Citrus	6.6m x 3.3m	450	every 2nd row, every 4th tree	100ml	6.3L	\$3.50
Figs	5m x 2m	1135	every 2nd row, every 5th tree	100ml	5.3L	\$2.93
Prunes	6m x 6m	272	every 2nd row, every 2nd tree	100ml	6.9L	\$3.82
Stonefruit	6m x 4m	420	every 2nd row, every 4th tree	100ml	5.3L	\$2.93
Walnuts	7m x 5m	300	every 2nd row, every 2nd tree	100ml	6.9L	\$3.82

Table 2.2 – Cost estimates for Maximum Crop Coverage

Crop	Total Ha*	Cost of Bait Spray/Ha†	Cost of Bait Spray/ Application	Labour & Bait Spray Cost/Ha @ \$7	Crop Duration (months)	Weekly Applications (4/month) Crop Present	Weekly Applications (4/month) @ \$7/Ha Crop Present	Foliage Present (months)	Weekly Applications (4/month) Foliage Present	Weekly Applications (4/month) @ \$7/Ha Foliage Present
Apples	1	\$2.93	\$2.93	\$7	6	\$70	\$168	8	\$93	\$224
Avocados	10	\$3.82	\$38	\$70	9	\$1,368	\$2,520	12	\$1,824	\$3,360
Cherries	300	\$2.93	\$880	\$2,100	3	\$10,560	\$25,200	9	\$31,680	\$75,600
Common Orange	500	\$3.50	\$1,750	\$3,500	5	\$35,000	\$70,000	12	\$84,000	\$168,000
Grapefruit	120	\$3.50	\$420	\$840	9	\$15,120	\$30,240	12	\$20,160	\$40,320
Mandarin	100	\$3.50	\$350	\$700	6	\$8,400	\$16,800	12	\$16,800	\$33,600
Lemon	108	\$3.50	\$380	\$756	6	\$9,120	\$18,144	12	\$18,240	\$36,288
Navel Winter	1,780	\$3.50	\$6,230	\$12,460	5	\$124,600	\$249,200	12	\$299,040	\$598,080
Navel Summer	1,400	\$3.50	\$4,900	\$9,800	5	\$98,000	\$196,000	12	\$235,200	\$470,400
Valencia	4,460	\$3.50	\$15,610	\$31,220	12	\$749,280	\$1,498,560	12	\$749,280	\$1,498,560
Figs	1	\$2.93	\$2.93	\$7	4	\$47	\$112	6	\$70	\$168
Prunes	885	\$3.82	\$3,380	\$6,195	4	\$54,080	\$99,120	8	\$108,160	\$198,240
Stonefruit	40	\$2.93	\$117	\$280	6	\$2,808	\$6,720	9	\$4,212	\$10,080
Walnuts	1,365	\$3.82	\$5,214	\$9,555	3	\$62,568	\$114,660	7	\$145,992	\$267,540
						Total Estimated Cost	Total Estimated Cost		Total Estimated Cost	Total Estimated Cost
						\$1,171,021	\$2,327,444		\$1,714,751	\$3,400,460

*Total hectares (Ha) refers to plantings in the Riverina area which includes the Local Government areas of Carrathool, Griffith, Leeton, Murrumbidgee, Narrandera

†Cost of Bait Spray/Ha figures for each commodity are from Table 2.1

Table 2.3 – Cost Estimates for Vineyard Bait Spray Coverage

Size of Farm	Percentage of Total Area	Total Area (22,000ha)	Average Headposts/Ha	Spray Pattern (every 6th post)/Ha	Application Rate (per post)	Approx Litres/Ha	Approx Cost/Ha	Cost of Bait Spray/ Application	Weekly Application (4/month) Crop Present	Weekly Application (4/month) Foliage Present
< 20 Ha (Small)	48%	10,560	16.5	2.75	100ml	275ml	0.02	\$211	\$3,376	\$6,752
20 - 100 Ha (Medium)	42%	9,240	6.1	1	100ml	100ml	0.0055	\$51	\$816	\$1,632
> 100 Ha (Large)	10%	2,200	4.2	0.7	100ml	70ml	0.0038	\$8	\$128	\$256
								Total Estimated Cost	Total Estimated Cost	Total Estimated Cost
								\$270	\$4,320	\$8,640

Table 2.4 – Cost Estimate for Total Autumn Vineyard Bait Spray Coverage

Crop	Spacings (metres)	Vines/Ha	Spray Pattern	Application Rate	Approx Litres/Ha	Cost Spray/Ha	Total Cost of 1 Application	Weekly Applications (4/month)
Grapevines	3.3m x 1.8m	1650	every 4th row, every 8th vine	100ml	7L	\$3.87	\$85,140	\$340,560

Assumptions for Costings and Spray Application

- It must be acknowledged that non-fruit bearing trees may **not** be sprayed, therefore reducing the total hectares figures in Table 2.2.
- Individual growers would fund the cost of a bait spraying program on their own properties.
- Most growers will have the equipment to undertake such a program.
- If a contractor was employed to carry out a bait spray program the cost would be approximately \$7 per hectare, per application, to bait spray commercial horticulture crops, excluding grapes/vineyards as the per hectare figure is determined differently.
- For the purposes of employing a contractor, 10 hectares would take approximately 1 hour to spray, on average.
- The wine grape industry is very limited on what chemical can be used due to restrictions on chemical traces in wine. Before making any chemical applications for fruit fly the grower should always consult with their winery to ensure correct compliance is achieved.
- Bulk purchases of chemical and yeast protein at competitive prices from Agricultural Product Distributors to be negotiated by individual commodity groups.

Funding Opportunities for the Control Program

At this stage all coordination of such a control program would be done on a voluntary basis and the workload would be onerous. Ideally, for the program to succeed and remain sustainable, a project officer would need to be employed, at least part-time, to successfully coordinate and implement RBC's plan for a grower-driven crop control program. If funding can be secured to appoint a project officer, the responsibilities of this role have been prioritised in Section 7 of this report.

A proposed budget for the project officer's role is included in Table 3.0 on page 16 of this report.

1. Under the Agricultural Industry Services Act 1998, RBC needs to investigate a possible levy to be implemented to help fund a fruit fly control program.
2. Horticulture Australia Limited (HAL) – RBC to submit an application to fund a project to assist the Riverina fruit fly control program.
3. Approach CA through the Industry Advisory Committee (IAC) for potential access to residual funds from the Riverina Citrus Pest Free Area Project.
4. MIA Fruit Fly Committee has some limited funds. RBC can approach MIA Fruit Fly Committee to determine if the funds can be utilised for the purpose of the fruit fly control program.
5. Commodity groups may hold a small amount of funding which they are willing to contribute to RBC for the purpose of the control program i.e. Leeton & Griffith Citrus Growers and Prunes.
6. RBC to appeal for the levy collected from horticultural farms in the Riverina by LHPA (Livestock Health and Pest Authorities), to be used for the purpose of the fruit fly control program.
7. The five Local Councils may allocate a small amount of funding for the control program, or, provide street bait spraying services and tree removals in their respective communities. In-kind work from councils e.g. brochures distributed in rates notices.

Table 3.0 - Proposed 12-Month Budget for Fruit Fly Control Program Project Officer

Expenditure	
A. Staffing Costs	Planned 12 Month Budget (excl GST)
Project Officer (based on 1.0 FTE)	\$58,000.00
Management Support (RBC)	\$3,000.00
Sub Total Section A	\$61,000.00
B. Administrative Costs	
Insurance	\$500.00
PC Workstation/s	\$2,000.00
Computing Expenses	\$1,300.00
Office Rent	\$4,000.00
Vehicle Expenses	\$1,330.00
Travel	\$10,000.00
Publications & Printing	\$1,500.00
Venue Hire & Catering	\$1,000.00
Advertising	\$1,000.00
Administrative Costs (power, mobile phone, postage, copy, stationary, cleaning)	\$2,500.00
Sub Total Section B	\$25,130.00
Total Expenditure (A + B)	\$86,130.00

If a project officer was to be employed, RBC must determine if it will be a full-time or part-time position. This will largely be dependent upon funding availability. If the position is to exist, other considerations to be made would be:

- Availability of a vehicle - RBC need to ascertain if purchase of a vehicle would be possible or if it would be more financially viable for the project officer to be reimbursed for the use of their own vehicle. Mileage rates would be paid at the current ATO cents per kilometre rate.
- Office Space – It is recommended that RBC would rent an office for the project officer through an external organisation who has spare office space available. This will reduce the overall administrative set-up costs. If suitable, the project officer could also be based from home.
- Length of Project – Ideally a 3-year project would enable the goals and objectives of this program to be achieved.

6. Mechanisms for Total Crop Coverage

NSW Government Gazette “Plant Diseases (Treatment and Eradication of Queensland Fruit Fly, Riverina) Order 2011”

RBC needs to review this order and put forth a request and recommendation to NSW State Government Minister for Primary Industries to amend Schedule 2 of this order. Currently, Schedule 2 of the order states that “All Cultivars of the genus Citrus and Vitis” and “All Cultivars of the species *Prunus domestica*” are subject to the terms of the gazette, effectively, citrus, grape and prune crops. This leaves a large amount of fruit fly susceptible crops in the region vulnerable, and potential primary hosts for a fruit fly outbreak. The order ideally would cover the aforementioned and:

- Avocados
- Cherries
- Figs
- Pome Fruit (Apples, Pears, Quince)
- Stonefruit (Peaches, Apricots, Nectarines)
- Walnuts

The gazette can be found at the following link:

http://www.nsw.gov.au/sites/default/files/No_45_of_2011.pdf

Other amendments to this Plant Diseases Order may need to be considered.

Routine Bait Spraying Program

This will form the foundation of an overall grower-driven fruit fly control campaign. RBC need to determine the ideal length and frequency of routine bait spraying for commercial crops in the area. During the period when fruit is beginning to develop on the trees, through to maturation, bait spraying would be scheduled weekly, fortnightly or monthly. When a horticulture crop has ceased producing fruit, or all fruit has been harvested, the intervals between bait spraying would naturally decrease. A decision needs to be made as to whether bait spraying would completely cease during the crops’ dormant periods when there is no fruit, or in some cases, no leaves on trees.

Based on the information on page 8 of this document and the approximate figures in Table 3.0, RBC is to develop a generic fact sheet and spray schedule for distribution to growers. When developing the spray schedule, RBC needs to take into consideration climatic and seasonal factors such as rainfall, humidity and temperature and adjust the spray schedule accordingly.

Queensland Fruit Fly Baiting Workshops and Shed Meetings

RBC are organising two information nights and five workshops to be held in Leeton, Griffith and Hillston. The workshops will be presented by Andrew Jessup from NSW DPI and Dan Papacek from Bugs for Bugs. RBC needs to promote these workshops to ensure maximum grower attendance which will increase grower awareness and education of the fruit fly control program.

Fruit Fly Baits and Traps

In addition to a bait spraying program, growers have the option of using MAT cups (male annihilation techniques), or traps installed in a geographically appropriate location on a property to monitor the presence of fruit fly. Information on where to obtain other fruit fly control equipment would be distributed to growers by RBC.

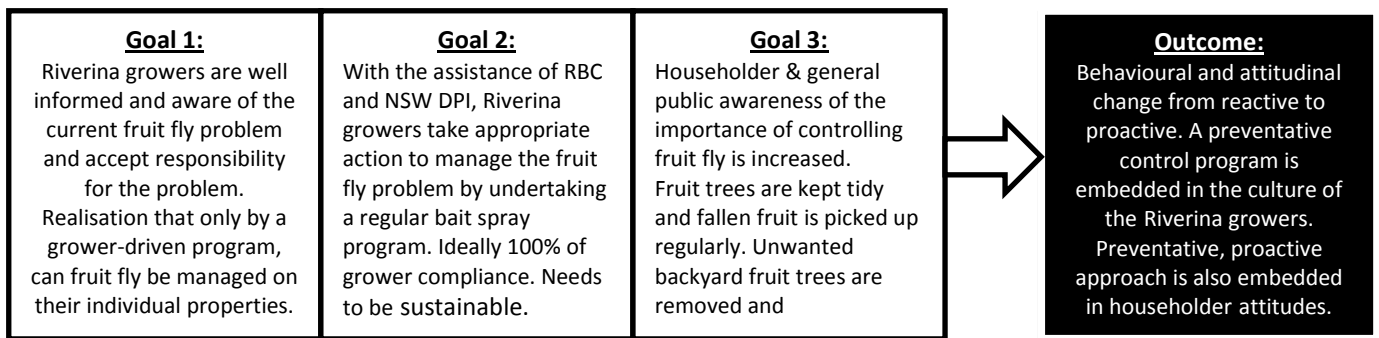
Field Officers & Purchasing Officers

Wineries, wine grapes marketing board, prune growers all have field officers and Citrus Processors also have purchasing officers. RBC is to communicate with these organisations and recommend their field and purchasing officers distribute updates and information and to encourage adherence to the bait spray program.

7. Communications Strategy

A successful communications strategy needs to incorporate a planned sequence of messages that will reach the target audience, this being growers and householders. When considering the appropriate communications strategy for the grower-driven fruit fly control program, the goals and outcomes of the program must be clearly defined.

Figure 2: Goals and overall outcome of the Fruit Fly Control Program



RBC's communication strategy will need to include the use of newspaper, television, electronic media and radio mediums that will convey the message to the individual grower and the householder.

Community Service Advertising

Community Service advertising is to be delivered by means of television and radio announcements. These announcements have been broadcast in the past, but will need to be reviewed to convey the current message.

Newspaper Articles

RBC to request a regular monthly "fruit fly program update" to be published in local papers, and also request commodity groups submit articles for publication on a regular basis. Paid advertising will not be an option due to restricted funds.

Other print media

Articles to be developed for publication in local council newsletters and local grower organisation newsletters.

Electronic Media

- **Facebook page** development by RBC. If this is not feasible, regular contact with local councils and grower organisations to request fruit fly alerts and updates to be posted on their respective Facebook pages.

- **Email & SMS Alerts** - Once a Riverina grower database is established, this will enable RBC to quickly distribute fruit fly “hotspot” information and alerts to growers in relevant districts via email and SMS.
- **iPhone/smart phone application** development for timely communication and promotion of the fruit fly control program.
- **Websites** – RBC can utilise existing websites e.g. WGMB and local councils. A list of recommended websites for growers and householders to visit and receive updated information is to be compiled.

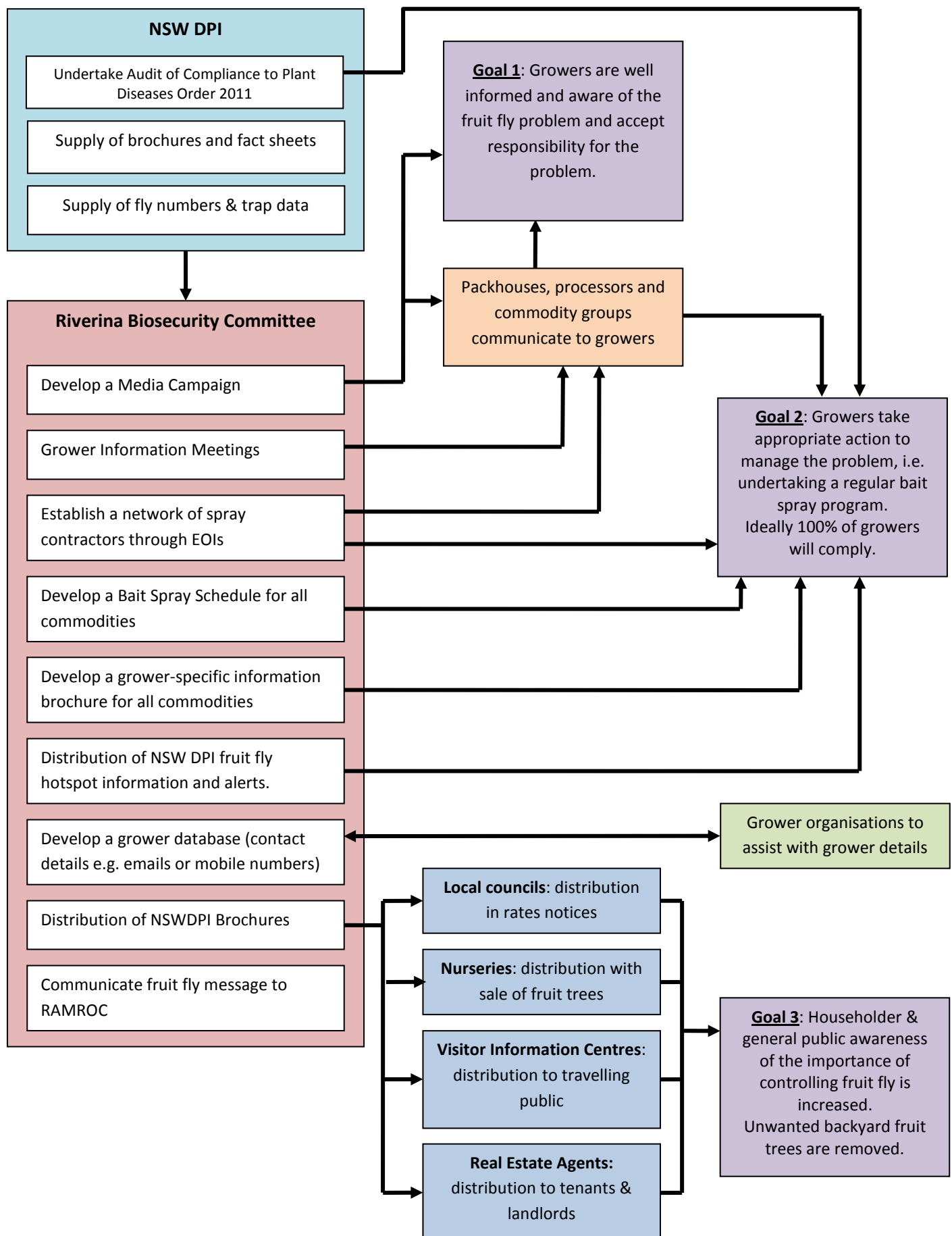
NSW DPI will be an integral part of the communications strategy by:

- Supplying RBC with copies of fruit fly brochures and fact sheets for distribution to local councils, visitor centres and nurseries.
- Supplying RBC with fly numbers and trap data to enable RBC to convey relevant information to growers, contractors and packhouses in a timely manner.
- facilitating grower information days and shed meetings
- An audit of grower compliance to the *Plant Diseases Order 2011* will be undertaken in spring 2012. This will be advertised, hence reminding growers of their responsibility to bait spray.

RBC will need to communicate the fruit fly message with other stakeholders such as:

- MI: discuss the removal of feral fruit trees from MI land, i.e. channel banks.
- RAMROC: promotion of fruit fly program in areas outside the Riverina.

Figure 3: Communication Flow Chart for Implementation of a Control Program



8. Recommendations for future of the control campaign

Of the twelve stakeholders identified below, prioritised recommendations have been made which target the responsibilities and required actions of each stakeholder. Currently, timelines for some activities cannot be quantified due to finite funding and the uncertainty of where future funds will be obtained to successfully coordinate and implement each activity.

Most importantly, RBC has to focus strictly on the implementation of achieving maximum bait spray coverage as this will determine the ongoing success of the control program and will affect all other activities. Regular bait spraying needs to be recognised by all stakeholders, particularly growers, as a fundamental activity in the management of fruit fly in the Riverina.

Stakeholder	Action & Responsibilities	When
Riverina Biosecurity Committee (RBC)	1. Set a date for the commencement of the bait spray program (ideally late-August 2012).	Immediately
	2. Fruit Fly Shed Information Days to be held in Leeton, Griffith & Hillston	13, 14, 15 August 2012
	3. Formulate bait spray program timetable, determining spraying intervals e.g. weekly, 10 days, fortnightly, monthly	Immediately
	4. Identifying ongoing funding opportunities to finance roll-out of the control program	Immediately
	5. Appointment of a Fruit Fly Control Program Project Officer	End August 2012
RBC Fruit Fly Control Program Project Officer	1. Introduction and communication with all stakeholders	Early September 2012
	2. Coordination of Media Releases	Immediately (after appointment of Project Officer)
	3. Put forth a request and recommendation to NSW State Government Minister for Primary Industries, Katrina Hodgkinson, to amend Schedule 2 of the <i>"Plant Diseases (Treatment and Eradication of Queensland Fruit Fly, Riverina) Order 2011"</i> to include all fruit fly susceptible commercial crops (i.e. apples, avocados, cherries, citrus, grapes, figs, prunes, stonefruit, walnuts)	Immediately (after appointment of Project Officer)

	4. Collation of a database comprising of individual growers, packhouses, fruit processors, commodity groups, local councils, agricultural product distributors and nurseries.	Immediately (after appointment of Project Officer)
	5. Analysis of NSW DPI trapping numbers and distributing relevant alerts to properties in affected "hotspot" areas	Daily/Weekly/Monthly
	6. Station a check-sheet at each agricultural product distributor outlet which will monitor sales of chemical and protein to be faxed/emailed back to RBC.	Late September 2012
	7. Design a standardised fruit fly fact sheet (along with design of a logo for RBC)	Late September 2012
	8. Communication to RAMROC (Riverina and Murray Regional Organisation of Councils). Widening the message to help emphasise the importance of this control program	October 2012
Individual Growers	1. Taking ownership of the fruit fly problem. Growers must acknowledge that there is in-fact, a problem.	Immediately
	2. Adhere to a spray program (which would include regular baiting and initially, where necessary, cover spraying)	August 2012 & Ongoing
	3. Change of attitude to the problem from a reactive to a proactive approach. "Fruit Fly Free" area not guaranteed under the current approach to the management of fruit fly.	Ongoing
NSW DPI	1. Printing and distribution of brochures and pamphlets	Ongoing
	2. Undertake an audit of compliance to the <i>"Plant Diseases (Treatment and Eradication of Queensland Fruit Fly, Riverina) Order 2011"</i>	September 2012 & Early 2013
	3. Establishment of suppression bocks in townships	Late Winter/ Early Spring 2012
	4. Fruit Fly spray program of townships in Riverina	Spring/Summer/Autumn 2012/13
	5. Unwanted fruit tree removal (backyards)	When required
Local Government Councils	1. Distribution of brochures and pamphlets to households via Rates notices	Quarterly (August, November, February, May)
	2. Brochures and information available at each Local Council office and Visitor Information Centres	Ongoing
	3. Town bait spraying of streets (not individual households)	Unknown

	4. Fruit tree removal in parks and council land. Ensure councils are conscious of not planting ornamental host-tree varieties.	Ongoing
Commodity Groups	1. Financial contribution to RBC to ensure ongoing viability of the committee.	Ongoing
	2. Encourage grower uptake of the bait spray program	Immediately after the spray program has been developed
	3. Negotiate bulk purchases of chemical and yeast protein with Agricultural Product Distributors. Commodity groups to ascertain what quantity of product needs to be purchased to receive a reduced price.	Ongoing
	4. Assist with collation of a grower registry/database	Immediately after Project Officer appointment
Citrus & Cherry Packhouses, Citrus Processors & Wineries	1. Encourage compliance of bait spray program	Immediately
	2. Audit of growers' spray diaries at specified times of the year. The frequency at which this task is performed would be the decision of each packhouse, processor or winery.	Ongoing - Periodically
Householders	1. Receival of brochures and community information, to assist households to understand their responsibilities to help contribute to the control of fruit fly.	Ongoing
	2. Spraying of fruit trees if appropriate	Ongoing
	3. Organising removal of unwanted fruit trees and regularly picking up fallen fruit from the ground	Ongoing
Real Estate Agents/ Landlords	1. Distribution of fruit fly brochures and fact sheets to property tenants	Ongoing
	2. Encourage property owners to remove unwanted fruit trees	Ongoing
Nurseries	Distribution of fruit fly information brochures and fact sheets with the sale of fruit trees and ornamentals	Ongoing
Visitor Information Centres	Distribution of fruit fly brochures and fact sheets to visitors	Ongoing
Murrumbidgee Irrigation	Removal of feral fruit trees from their land	Ongoing

Mechanisms to Monitor the Success of the Campaign

1. Trapping numbers and information

A decrease in the number of fruit fly caught will indicate spray program is having an effect, or, conversely, if the trapping numbers are increasing, there needs to be a review of the spray program and other associated program activities.

2. Monitoring Infested Fruit Rejections

A formal system of monitoring infested fruit rejections from packhouses, processors (juice factories) and markets needs to be implemented. A streamlined reporting process needs to be developed which will see this information from AQIS, NSW DPI, individual packhouses, processors, wholesale markets and supermarkets, being reported directly to the RBC Project Officer for immediate action.

3. Monitoring Results of NSW DPI Compliance Program

Senior Compliance officers from NSW DPI will notify RBC of any breaches to the Compliance program. RBC to follow-up any grower breaches to determine the reason they have occurred

4. Monitoring chemical & yeast protein sales

An increase in sales volume would assume that growers are bait spraying their farms. Stagnant sales may indicate that the bait spraying program has not been adopted by larger numbers of growers. This would require further investigation of the amount and frequency at which growers are purchasing chemical and yeast protein. Greater awareness is needed by means of improved communication. If sales are decreasing, undoubtedly there is a major problem and the RBC needs to devise and apply alternative approaches to the issue.

5. Verbal communication and feedback between growers and/or contractors

This mechanism would track non-compliance and indicate if some or no coverage is being achieved in certain districts. A grower who undertakes a vigilant spray program will not tolerate a neighbour who is not taking part in the control program.

6. Communication with, and feedback from, NSW DPI Horticulturalist and field officers

A process needs to be implemented to allow feedback from field officers (WGMB and citrus packhouses currently have field officers and Prunes Australia have recently advertised for a field officer in the Griffith area) and the NSW DPI Horticulturalist to be reported weekly or monthly to the RBC. A report template to be created to simplify and streamline this process so each party is able to email the report to the RBC in a timely manner.

7. Communication with, and feedback from Riverina IPM Pty Ltd

Same process as point 6 above.

Glossary

CA: Citrus Australia

NSW DPI: New South Wales Department of Primary Industries

EOIs: Expressions of Interest

FTE: Full-Time Employment

HAL: Horticulture Australia Limited

IAC: Industry Advisory Committee

IPM: Integrated Pest Management Pty Ltd

RAMROC: Riverina and Murray Regional Organisation of Councils

RBC: Riverina Biosecurity Committee

RC: Riverina Citrus

WGMB: Wine Grapes Marketing Board