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The New Zealand Institute for Plant & Food Research Limited

The potato psyllid, *Bactericera cockerelli*, at a global level: diagnostics and management options

Situación del psílido de la papa, *Bactericera cockerelli,* a nivel global: diagnóstico y opciones de manejo

Jessica Vereijssen, Rebekah Frampton, Grant Smith, Margaret Carpenter, Falk Kalamorz, Steve Lewthwaite

Workshop Phytosanitary emergency in the potato crop in Ecuador and implications for Peru and the Andean region: Purple top, potato psyllid and zebra chip, Lima, Peru, 20-22 January 2020

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Aimin Wen
Neil Gudmestad

Brendan Rodoni
Rachel Mann

Toni Chapman

Grethel Busot
Mohammad Arif
James Stack

New Zealand & main potato growing regions

Nueva Zelanda, regiones de cultivo de papa

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Tomato potato psyllid
psílido de la papa

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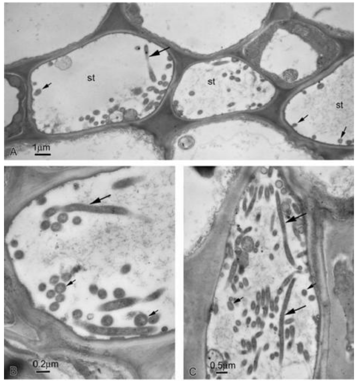
Bactericera cockerelli -

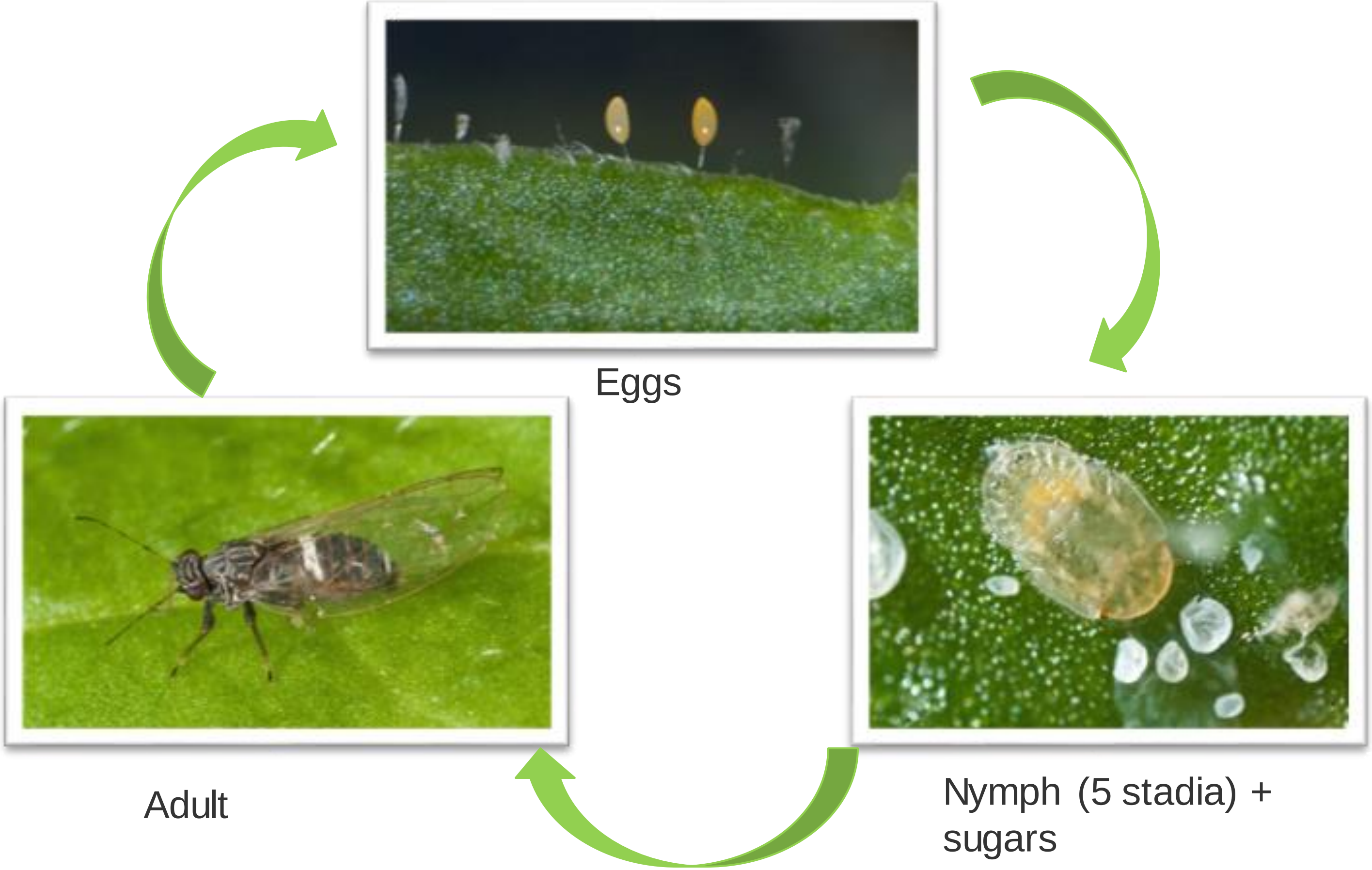
Tomato potato psyllid / TPP



Liefting et al 2009
Plant Disease

Candidatus Liberibacter solanacearum -
CLso / Liberibacter

TPP life cycle



Insect | Pathogen | Host plants

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History of TPP and CLso in New Zealand

2006 TPP found in tomato crop in New Zealand

2008 TPP in all major potato growing regions

2008 *Candidatus* Liberibacter solanacearum (CLso) – a new to science pathogen - confirmed in glasshouse capsicum crop

2008 CLso confirmed in potatoes showing zebra chip disease near Auckland

2009-2010 Average $700/ha extra agrichemicals

2020: growers apply insecticides on a weekly schedule, but zebra chip disease is still found in crops

Potato and tamarillo industry most severely impacted

Reduced yield and quality, increase management costs

(Ogden, 2012)

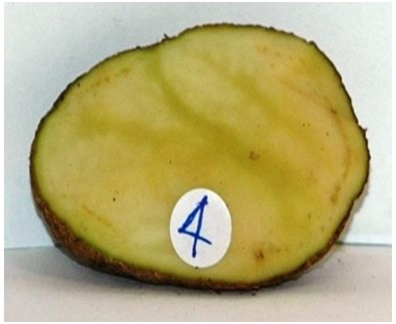
Review TPP & CLso in NZ: Vereijssen et al 2018. J. Int. Pest Man.

Zebra chip symptoms in NZ differ from the ones in the USA

- Less dominant striping in fried slices
- Different biological results
- Infected tubers sprouted (sensitivity of assays)
- Different described epidemiology
- Cultivar, environment, cultivation practices, vector behaviour
- The more ‘aggressive’ CLso-B variant is not present in NZ, only CLso-A

USA (Texas)

New Zealand (Pukekohe)



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Reciprocal BLAST to identify unique genomic regions in CLso-A

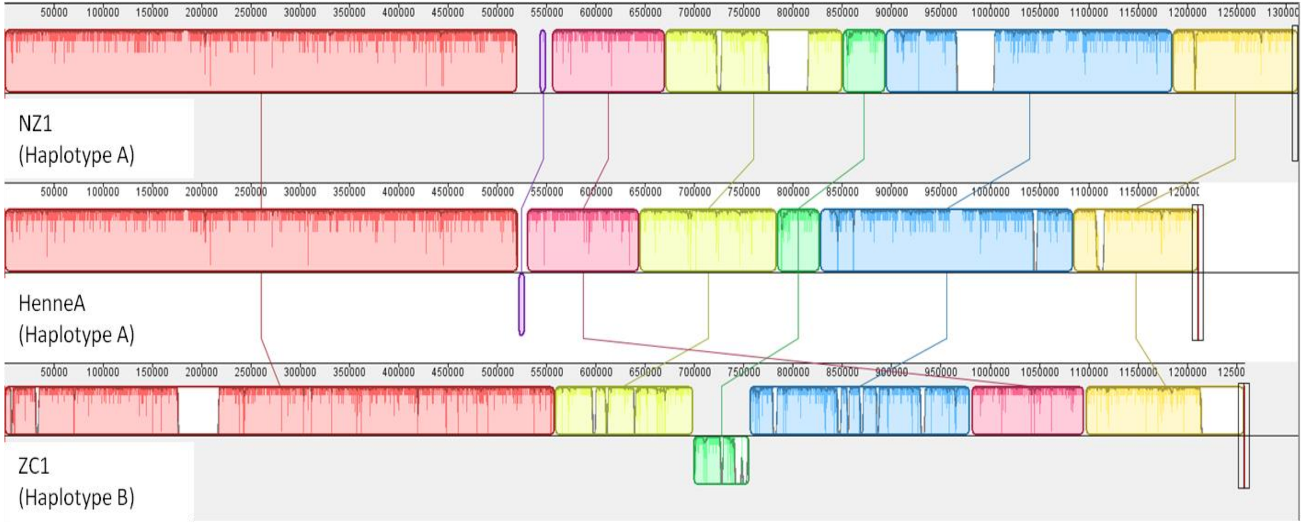
Phytopathology 105:863-871

Bacteriology

e-Xtra*

Genomes of ‘*Candidatus* Liberibacter solanacearum’ Haplotype A from New Zealand and the United States Suggest Significant Genome Plasticity in the Species

Sarah M. Thompson, Chris P. Johnson, Ashley Y. Lu, Rebekah A. Frampton, Kerry L. Sullivan, Mark W. E. J. Fiers, Ross N. Crowhurst, Andrew R. Pitman, Ian A. W. Scott, Aimin Wen, Neil C. Gudmestad, and Grant R. Smith



Grant smith

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Significant economic losses across NZ's horticulture industry

- Potato
  - 2008-09: NZ$47-56 M losses
  - 2010-11: NZ$28 M (NZ$6 M pest management)
- Tamarillo
  - 80 growers lost in 5 years
- Greenhouse tomato
  - 4-6% yield loss
  - 2011: NZ$5 M in pest management costs

(Ogden, 2012)

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Impact of TPP and CLso in potato

Pre-TPP & CLso

- Sprays for aphids and potato tuber moth only
- Very close to completion of potato IPM programme

Post-TPP & CLso

- Weekly insecticide applications, very often from emergence
- New insecticides are expensive, affecting profit
- Less yield (reduced emergence, smaller tubers)
- More rejects (tubers & fries) at the process factory
- Rejected seed crops
- More crop scouting
- Consumer dissatisfaction (fresh, chips, crisps)
- NZ$ 50M per annum in crop losses, plus NZ$ 12M in additional agrichemicals

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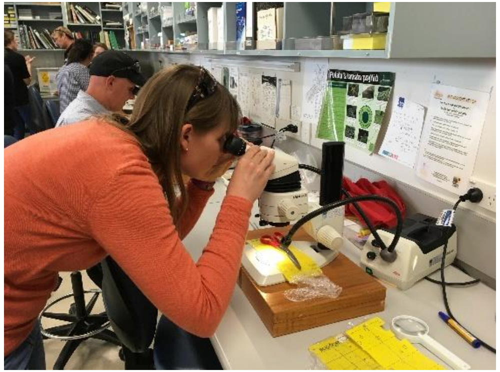
Working closely with growers and industry

- Co-innovation of research with industry
- Trials at grower properties
- Field days, project workshops, show and tell, industry groups
- Potatoes NZ annual conference
- Training TPP identification and CLso for agronomists and seed inspectors



Tomato potato psyllid diagnostics

diagnóstico psílido de la papa

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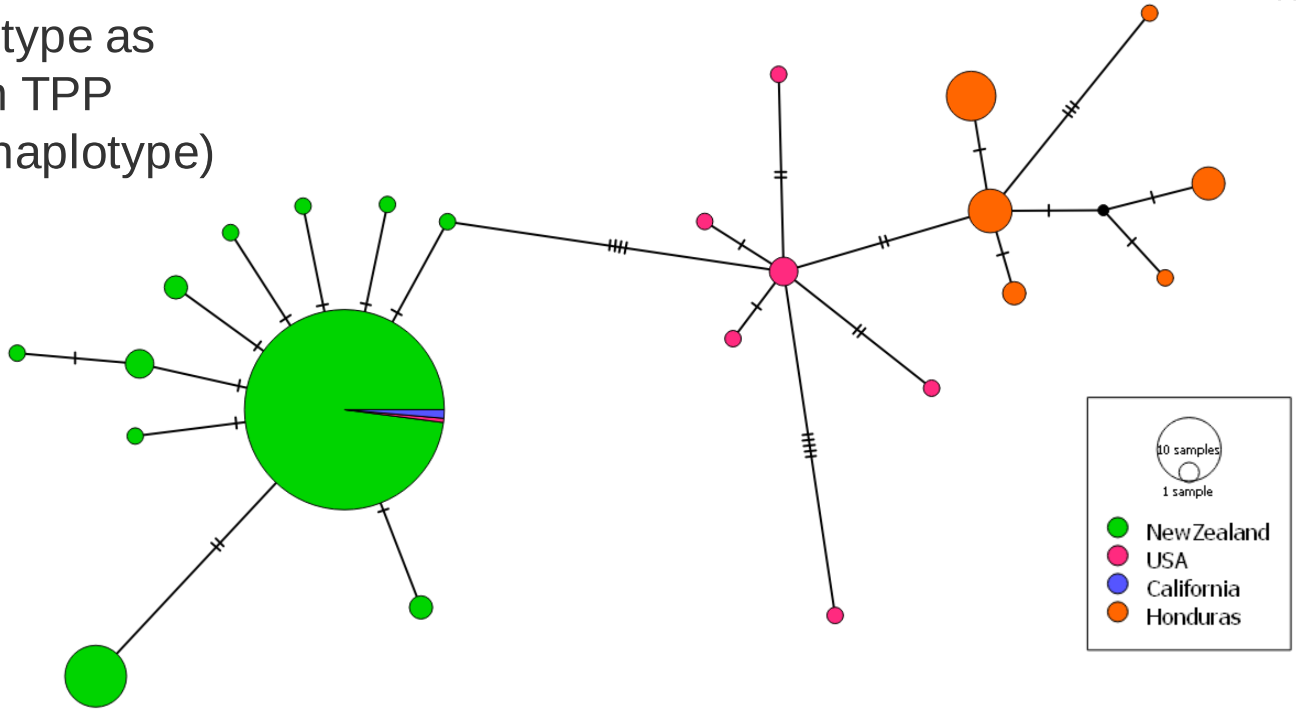
B. cockerelli diversity in New Zealand

Rebekah Frampton

- NZ TPP have same sequence type as Californian TPP (Western haplotype)



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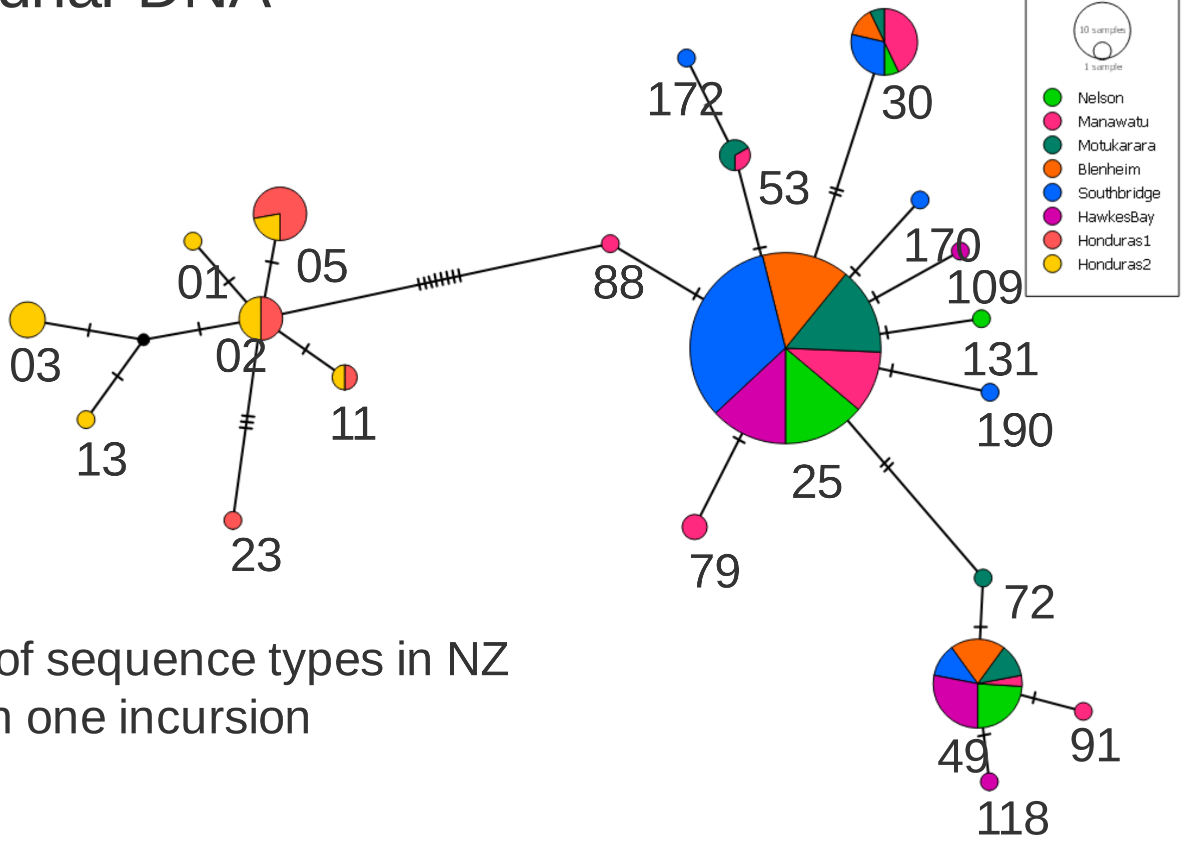
Mitochondrial DNA



Rebekah Frampton

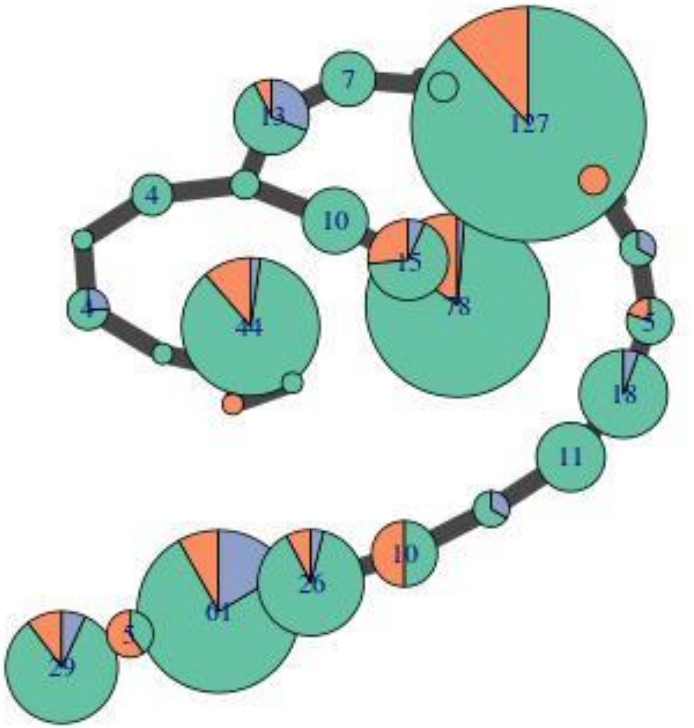
- Diversity of sequence types in NZ
- More than one incursion

Carsonella

Rebekah Frampton

A nutritional endosymbiont; bacteria produces essential amino acids that are lacking in the insect's diet.

- Well preserved area
- All sequence types present in NZ, California, and Honduras



Frampton et al 2019, poster, APPS

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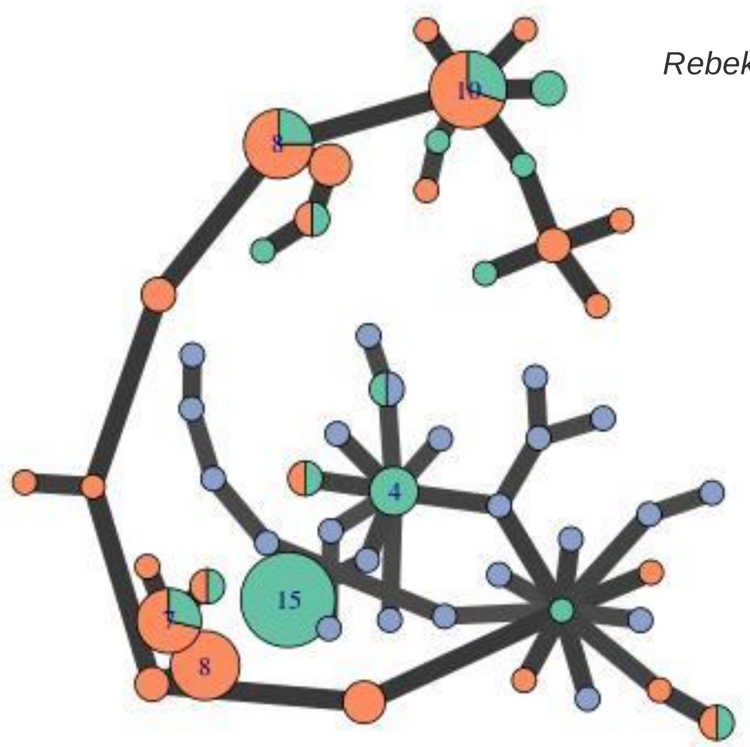
Wolbachia

Note: Only 24 samples from one area in California!

Rebekah Frampton

Endosymbiont that can manipulate host reproduction

- Several sequence types found in NZ and California
- Majority of Honduras sequences were different to those in NZ and California
- Only found in TPP populations in North Island and top of South Island



Frampton et al 2019, poster, APPS

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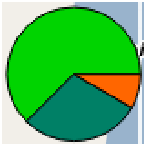
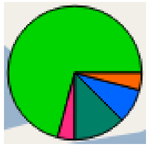
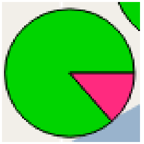
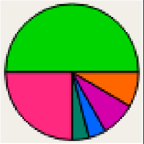
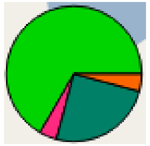
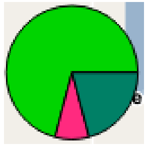
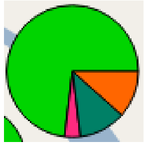
Seasonal variation in sequence types in growing regions

Mitochondria

2014/2015	Hawke's Bay	Manawatu	Nelson	Blenheim	Motukarara	Southbridge
Early						
Mid						
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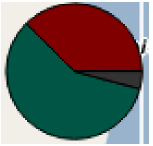
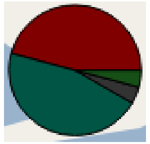
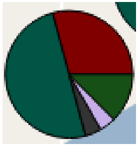
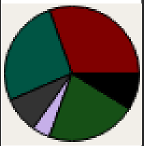
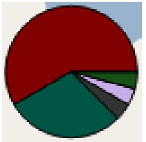
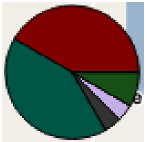
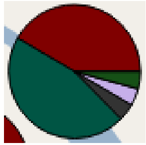
Rebekah Frampton

Carsonella

2014/2015	Hawke's Bay	Manawatu	Nelson	Blenheim	Motukarara	Southbridge
Early						
Mid						
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Frampton, in prep

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Host plants
Plantas hospederas

Host plant surveys around crops

Host plants of TPP and CLso are not restricted to crop species, and include weed species, which provides challenges for surveillance, eradication and management

- All TPP life stages were present on non-crop host plants throughout the year
- So they are not <u>alternative</u> hosts, but hosts
- Jerusalem cherry and thorn-apple tested positive for CLso in Hawke's Bay

Vereijssen et al 2015 New Disease Report

CRC PLANTbiosecurity

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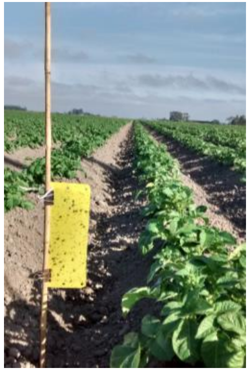
Spatiotemporal dynamics of TPP throughout the year

- There was a low background population of *B. cockerelli* flying around in the environment
- When African boxthorn was present adjacent to a crop, there was increased activity nearby and an edge effect may be observed in the host crop
- *B. cockerelli* multiplied in the crop but did not disperse far
- A desiccated crop increased adult flight in *B. cockerelli*



CRC PLANT biosecurity

Literature review of host plants

- 76 plants species confirmed as true hosts of *B. cockerelli*
  - 65 Solanaceae
  - 10 Convolvulaceae
- 2 plant species in Order Lamiales (family Lamiaceae and Oleaceae) identified as food plant
- 26 plant species partial hosts, 31 food plants, 57 casual plants, and 20 plant species for which the association could not be identified
- No species which fit ‘overwintering or shelter plant’ category
- Propose that host range of *B. cockerelli* is in the Order of Solanales. Critical to pest risk assessments, biosecurity agencies and research scientists, industry and growers

Vereijssen et al, in prep for Environmental Entomology

Pest management
Manejo de plagas

An incursion: what now?!

First response was to help industry and growers to manage TPP – all based on insecticides

Understanding the epidemiology of a vectored biosecurity pathogen is critical to effective, sustainable management

- Insect and plant hosts (vertical and horizontal transmission)
- Targeting the vector is not necessary targeting the pathogen
- Focus on the insect and the pathogen (transmission type)

2020 - there are still many questions that need to be answered

Biological control

Control biológico

Biological control agents naturally present in potato

Lacewings
Hoverflies
Ladybirds
Spiders

Keep TPP populations under control early season only

Seasonality in occurrence, first lacewings, then hoverflies

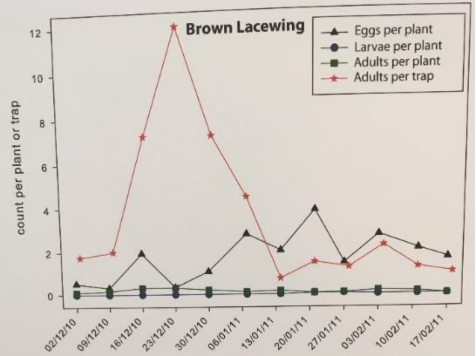


Figure 2. Brown lacewing sticky trap and plant monitoring results

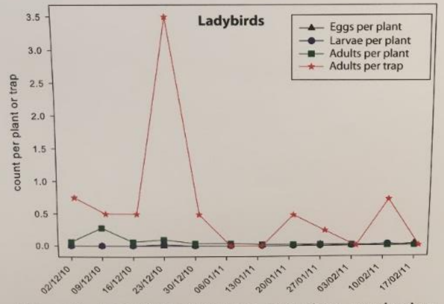


Figure 3. Ladybird sticky trap and plant monitoring results

MacDonald et al 2010 NZ Plant Protection
Jorgensen et al 2011 NZ Plant Protection
MacDonald et al 2016 NZ Entomologist

Introduced biocontrol agent: *Tamarixia triozae*

Melanie Davidson

Hymenoptera: Eulophidae

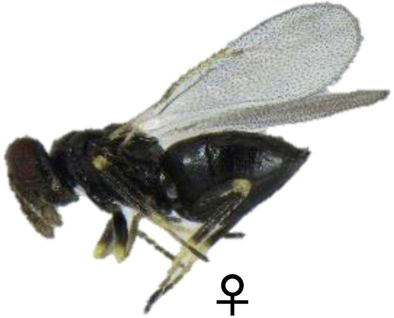
Primary, solitary, arrhenotokous, ectoparasitoid

Adults predate on 1st and 2nd instars

A single egg laid on the underside of the nymph 3rd-5th instar

Parasitoid develops within the remains of the psyllid nymph

A single female can lay up to 165 eggs during her lifetime



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Manatū Ahu Matua

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Assessing Limonicus mite as control agent

Amblydromalus limonicus a predatory mite

Potential to suppress TPP populations on pepper but not tomato cultivars

Focus on indoor crops

Kean et al 2019 Pest Man. Sci.

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Cultural control

Control cultural

Cultural options for TPP management

Crop covers

- Problems with aphids under the mesh cover
- Low yields as a result
- No TPP / zebra chip found under mesh
- Still not commercially used – too many practical issues
    - Seed inspector access to plants/tubers
    - Pivot irrigators
    - Cost and special machinery needed

Potatoes™ NEW ZEALAND Growing together

FAR

BHU GROWING ORGANICS

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Cultural options for TPP management

Roguing plants with symptoms – seed crop

- Conducted by growers and seed inspectors
- Tolerance at 0.2% for G1 – G6 (and zero for G0)
- All seed lines have two inspections, some cultivars three

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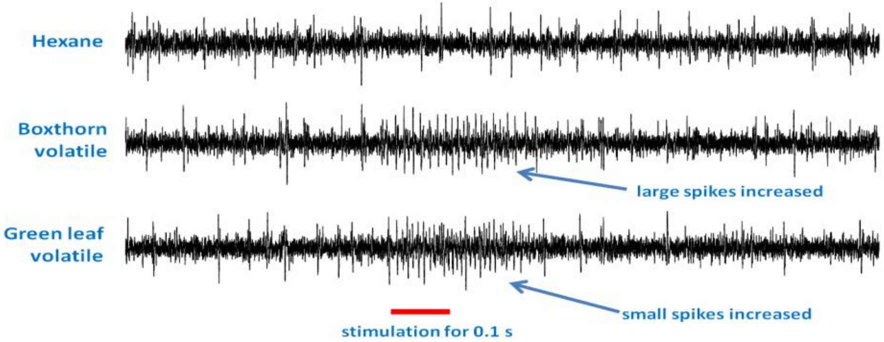
Cultural options for TPP management

Kye Chung Park

Semiochemicals

- derived from host plants
- currently being tested in the field
- probably not useful in potato, but useful in greenhouse crops
- Added LED light to trap to hopefully to increase attraction



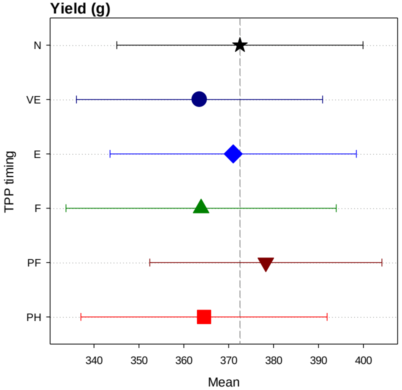
Chemical pest management

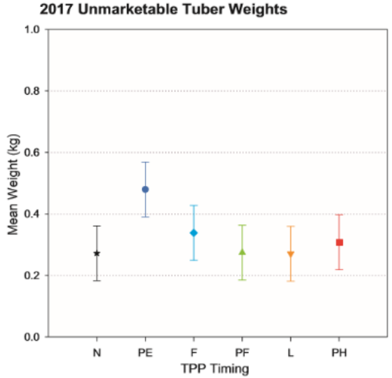
Manejo de plagas químicas

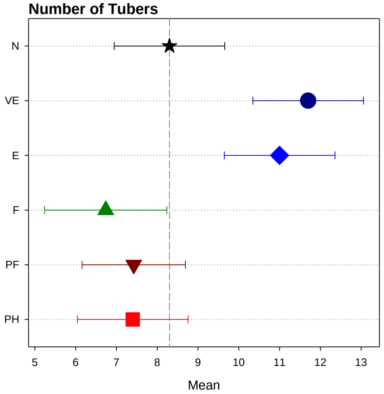
Do CLso-free TPP have an effect on tuber set?

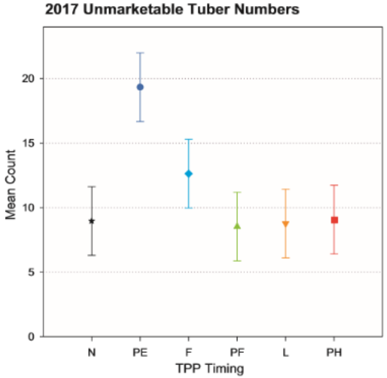
Yes, when infected before flowering

Shade house and field experiments









Pitman, Vereijssen, Weintraub 2014 Poster @ Hemipteran-Plant Interactions Symposium
Pitman et al, in prep.

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Chemical pest management options in NZ

Agricultural oils

- Repellent / anti-feeding / suffocation
- Promising results in field trials Canterbury
  - alternate with agricultural oil after two spirotetramat sprays

Botanicals

- Tested, but not used in potatoes in NZ

Insecticides

- Primarily used
- Fear of insecticide resistance (aphids)
- Use on re-growth after desiccation
- New insecticides benign to predators

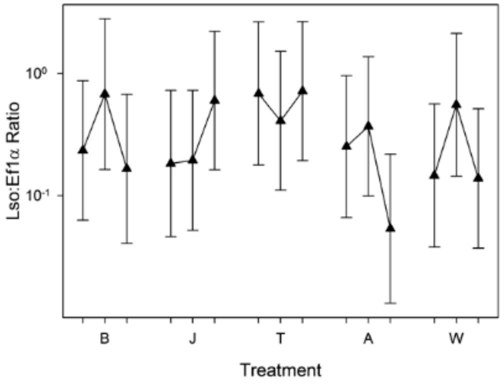

Figure 2 The mean ratio between *Candidatus* Liberibacter solanacearum (CLso) and EF1α genes for each treatment at each of the three tomato potato psyllid (TPP), application times in the additional trial (ticks on X-axis indicate 1, 3, and 7 days after treatment). A smaller ratio indicates a lower quantity of CLso gene present in the sample. Error bars are approximate 95% confidence intervals for the means. B = Benevia®, J = Organic JMS Stylet-Oil®, T = Thunderbolt, A = Avid®, W = Water.

Barnes et al 2015 NZ Plant Protection

Spray programme evolution 2009 - 2019

Weekly spray programmes
- Resistance management

Reduced spray programmes
- Plant threshold
- Trap threshold
- Degree Days
- Early crops (NI)
- Extended spray intervals X
- Selective insecticides
- Resistance management

Regional reduced spray programmes
- Trap threshold
- Degree Days
- Agricultural oils
- Selective insecticides
- Resistance management

Reduced spray programmes NI
- Trap threshold
- Agricultural oils
- Selective insecticides
- Resistance management

Future proofed reduced spray programme Canterbury
- (Trap threshold)
- Degree Days
- Agricultural oils
- No organophospate and synthetic pyrethroids
- Selective insecticides
- Resistance management

Walker et al 2013 NZ Plant protection
Walker et al 2015 Am. J. Pot. Res.
Vereijssen et al several industry reports

Potatoes New Zealand
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Sustainable Farming Fund
Plant & Food Research Rangahau Ahumāra Kai

Testing a future proof insecticide programme

	1 - SE	2 - AE	3 - SD	4 - AD	5 - F	6 - C
Week actual date of application	Canterbury Programme Weekly from emergence (positive control)	Alternating from emergence	Weekly from 716DD, Canterbury Programme	Weekly from 716DD, alternating	Future-proof spray programme	No spray control (negative control)
Planting 17 Oct 2018						
wk 1- Emergence						
wk 2 29 Nov	Chess®	Chess			Avid	-
wk 3 7 Dec	Movento® OD	Movento OD			Movento OD	-
wk 4 14 Dec	Movento OD + Avid®	Movento OD + Avid			Movento OD + Avid	-
wk 5 21 Dec	Benevia®	Benevia			Benevia	-
wk 6 28 Dec	Benevia	Excel® oil	Movento OD (28 Dec)	Movento OD (28 Dec)	Benevia	-
wk 7 3 Jan 2019	Avid	Benevia	Movento OD + Avid	Movento OD + Avid	Benevia	-
wk 8 11 Jan	Avid	Excel oil	Benevia	Benevia	Avid	-
wk 9 17 Jan	Sparta™	Avid	Benevia	Excel oil	Sparta	-
wk 10 25 Jan	Sparta	Excel oil	Avid	Benevia	Sparta	-
wk 11 31 Jan	Sparta	Avid	Avid	Excel oil	Sparta	-
wk 12 7 Feb	Tripsol®	Excel oil	Sparta	Avid	Sparta	-
wk 13 15 Feb	Tripsol	Sparta	Sparta	Excel oil	Transform™ 0.3	-
wk 14 21 Feb	Tripsol	Excel oil	Sparta	Avid	Transform 0.3	-
wk 15 1 March	Proteus®	Sparta	Tripsol	Excel oil	Transform 0.3	-
Ground storage						
Harvest 2 & 3 April	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest
Total sprays	14	9 + 5 oil	10	6 + 4 oil	14	0

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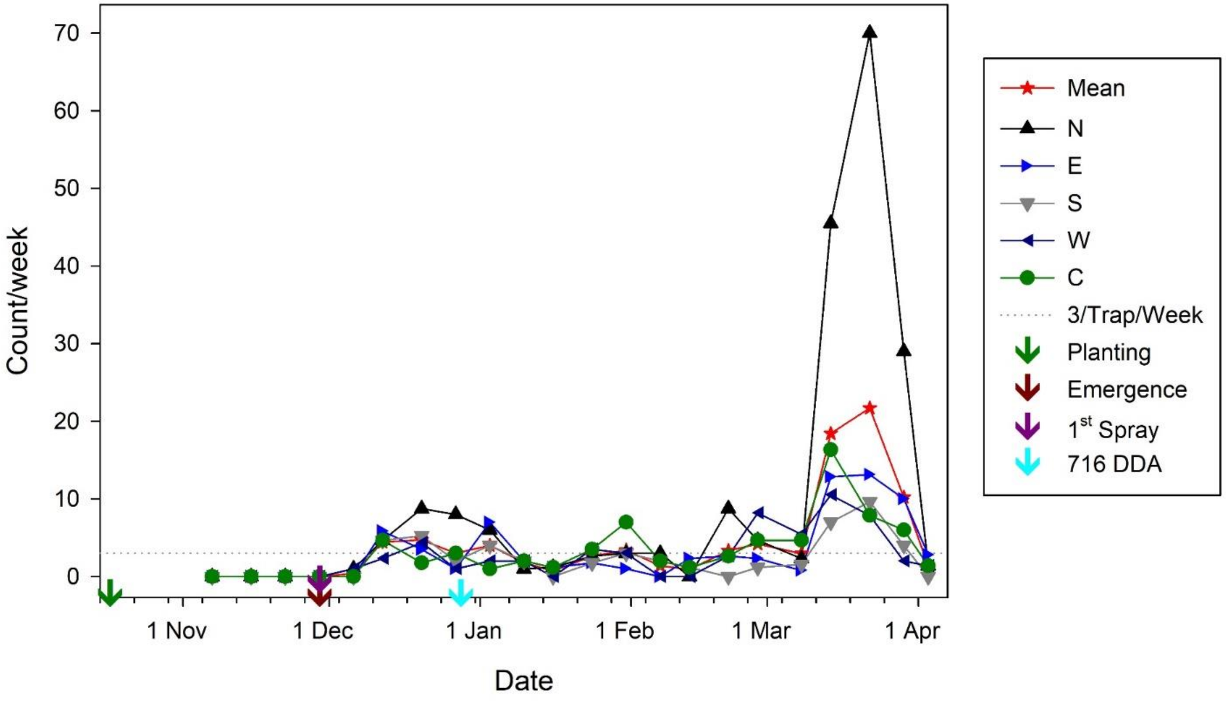
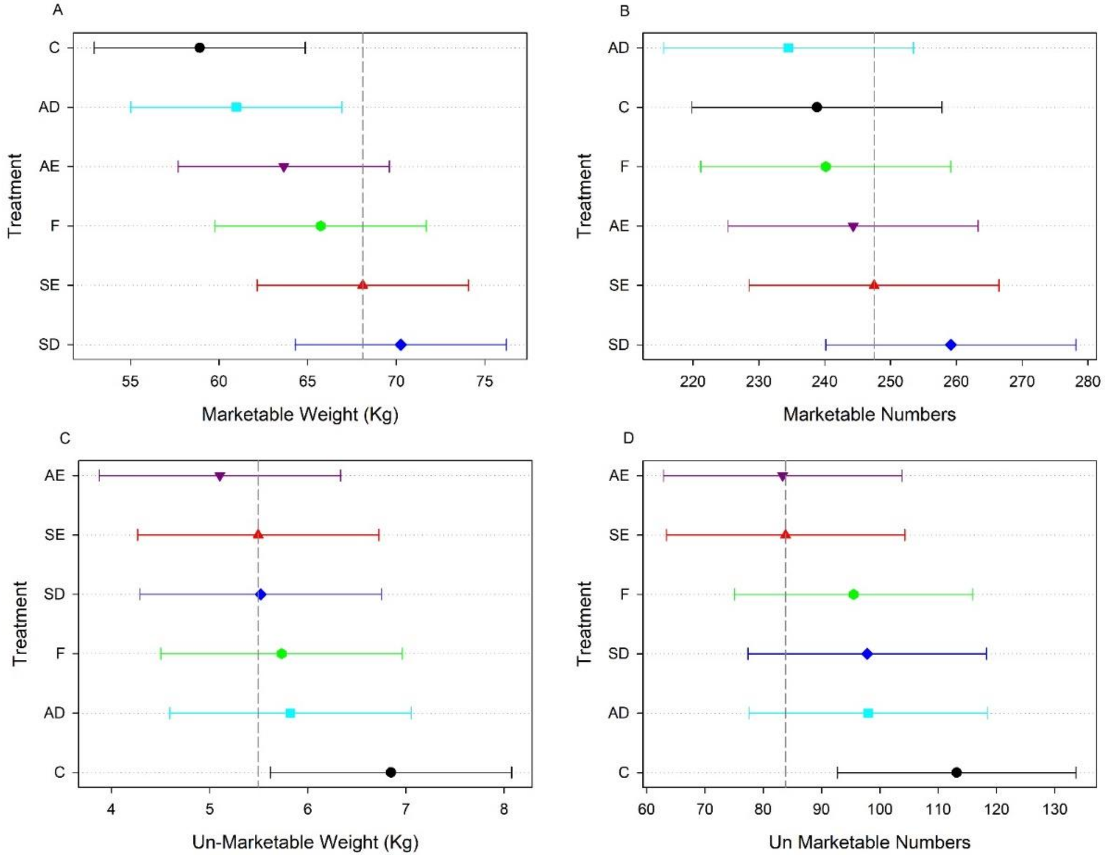
Not a very high psyllid pressure in 2018-19



Vereijssen et al 2019 Industry report

No significant differences in weights and numbers



Vereijssen et al 2019 Industry report

Potatoes NEW ZEALAND

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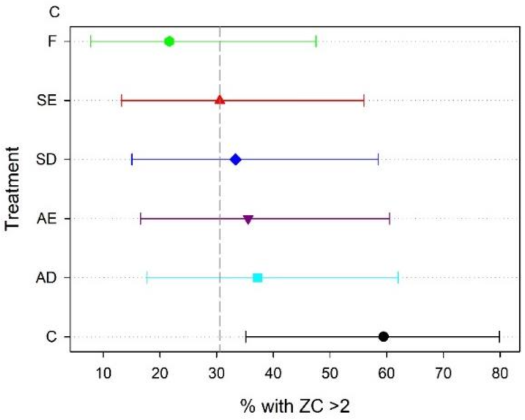
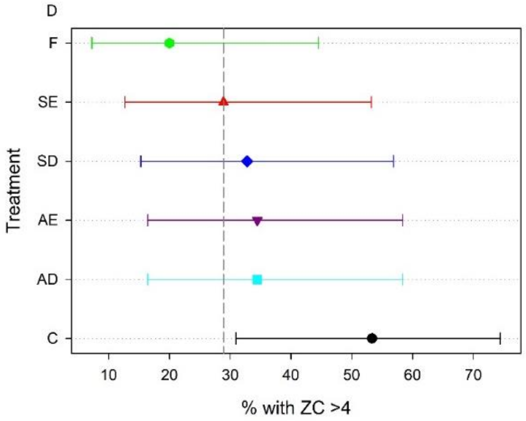
No significant differences in zebra chip severity





ZC: zebra chip disease

Treatment	ZC score
SE	2.33
AE	2.78
SD	2.57
AD	2.99
F	1.66
C	4.19
Lsd 5% (df=25)	2.32

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Overall, future proof programme scores best

Treatment	Number of insecticide sprays	Marketable weight in mean kg/plot	Marketable yield (t/ha)	% tubers with ZC>2	ZC adjusted marketable yield (kg/ha)[1]	Cost/ha ($)	'Profit' adjusted for ZC ($)[1]	Relative profit adjusted for ZC
SE	13	68.1	90.8	30.6	69525.3	1424.4	68100.9	100.0
AE	8 + 5 oils	63.7	84.9	35.6	62635.2	1240.3	61394.9	90.1
SD	10	70.3	93.7	33.3	70317.6	1100.2	69217.4	101.1
AD	6 + 4 oils	61	81.3	37.2	59280.9	991.5	58289.4	85.3
F	13	65.7	87.6	21.7	71980.3	1431.0	70549.3	103.5
C	0	58.9	78.5	59.4	49268.1	0.0	49268.1	70.9

[1] We assume here that growers get paid $1/kg of marketable potatoes, which turns the ZC adjusted marketable yield (kg/ha) into a dollar figure. This is then used to calculate the 'Profit' adjusted for ZC.

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Reduced spray programmes differ per region

	North Island	South Island
Agricultural oil incorporated	Good	Best results
Increased spray intervals early season	Good	Good
3 TPP/trap/week	Good	Too late
Degree day threshold	980 DD	712 DD, but…

Important: insecticide systemic or contact
Problems with re-growth after haulm desiccation
Different programmes needed for different potato end-uses

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One very important thing to remember

When managing an insect – pathogen – host plant complex:

No single approach will achieve adequate control;

an integrated approach to management is needed.

Cultural
Covers
Weed hosts
Volunteers
Roguing

Non-Cultural
Agricultural oils
Botanicals
Insecticides

Monitoring
Sticky traps
Plants
Other pest insects
Diseases

Tolerant and resistant cultivars

Cultivares tolerantes y resistentes

Transcriptomics glasshouse trial

Cultivar Moonlight, 3 replicates
Treatments:

- CLso+ psyllid
- CLso- psyllid
- Control C

TPP sprayed off after 2 days
Sampled leaf, stem and tuber after 7 weeks

Uninfected Infected

Infected Uninfected

Margaret Carpenter

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Genes showing biggest increases and decreases in expression CLso+TPP/-TPP

Margaret Carpenter

Leaf

Increases:

Heat shock proteins
Unknown
Peptidylprolyl isomerase

Decreases:

Auxin-induced SAUR
Unknown
Pectinesterase

Stem

Increases:

Oxidoreductase
Solanidine galactosyltransferase
Cellulose synthase

Decreases:

Dirigent
Unknown
Peroxidase
Linalool synthase

Tuber

Increases:

Metal ion binding protein
Heat shock protein
SWEET sugar transporter
Dormancy associated protein

Decreases:

Peroxidase
Pectate lyase
Glutaredoxin
Patatin

Carpenter, unpublished

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Transcriptomics results

Margaret Carpenter

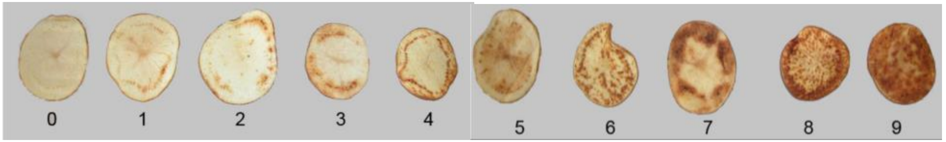
- Many genes showed changes in expression - more and bigger changes in tuber than in stem and leaf
- Gene expression shows tuber sugar metabolism is disrupted
- ZC triggers a range of typical disease responses
- Compared the transcriptomes of tolerant and susceptible lines in response to ZC. Many of the changes in gene expression are common to both lines, but there are a group of genes whose behaviour differs between susceptible and tolerant lines
- Understanding the potato plant's response to TPP and CLso, to inform breeding of tolerant or resistant cultivars and better management of the crop to achieve product quality

Carpenter, unpublished

Development of tolerant potato cultivars

Steve Lewthwaite

- Plant & Food Research developed a zebra chip tolerant French fry cultivar which is currently with a licensee and also identified other tolerant lines
- Other candidate Crop Number which is a proprietary breeding line shows heritable increase in zebra chip tolerance and is being used as a parent in the breeding programme
- Recently we identified a third breeding line with low zebra chip defect scores from greenhouse and field environments
- Tolerant cultivars will help to reduce zebra chip incidence and severity



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Anderson et al 2013 Am. J. Pot. Res.
Anderson et al 2019 Am. J. Pot. Res.

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Novel approaches

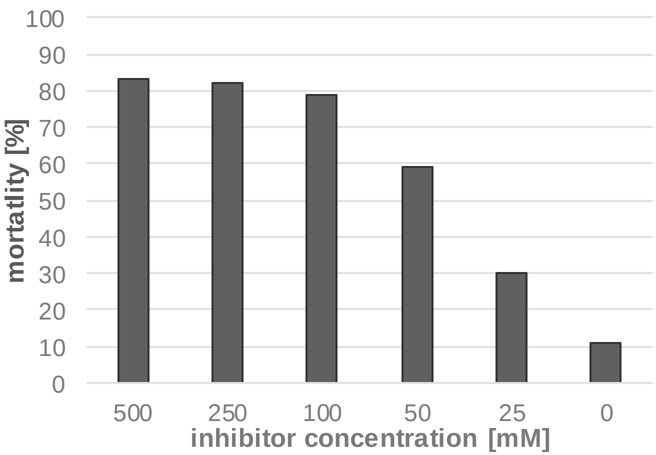
Enfoques novedosos

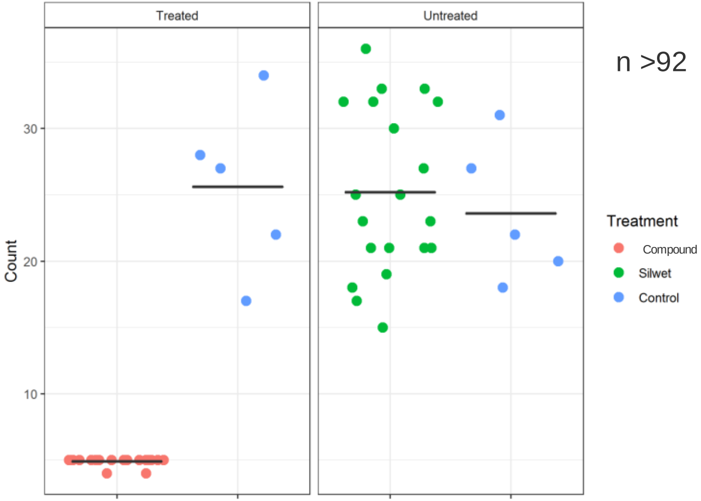
Testing novel control agents for TPP

Falk Kalamorz

Novel compounds targeting suborder Stenorrhyncha (psyllids, aphids, armored scale, whiteflies)

Highly specific & safe (LD50 in rats 24g/kg)





2 topical treatments over 7 days:

- 80% mortality in psyllids
- Arrests proliferation of aphids
- Next tests against beneficials (honey bee & ladybugs)

Kalamorz, unpublished

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Using psyllid vibration to disrupt mating

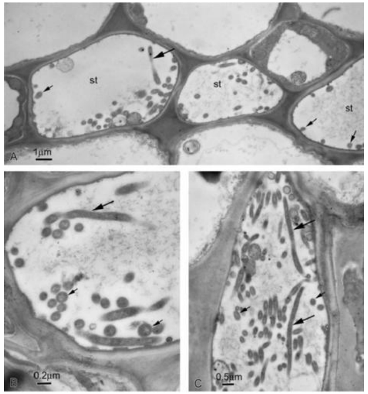
Kye Chung Park

- Wings are vibrating quite fast, which is not flight related, instead produced sound vibrations in the plant
- TPP use sound to locate each other on the plant
- Used laser vibrometer to listen to calls between males and females
- Female call made in response to the male call is used by males to locate females on the plant
- Investigating if synthetic female call could be used to lure and kill male psyllids, or for mating disruption

Sullivan et al, in prep

Other fundamental work that may lead to solutions

- Can we extract CLso directly from a living plant? – Falk Kalamorz
- Is there a Quorum Sensing component? – Grant Smith



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Thank you

@bugologists

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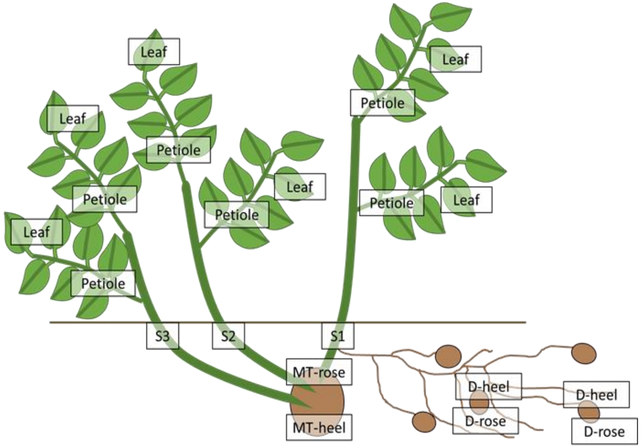
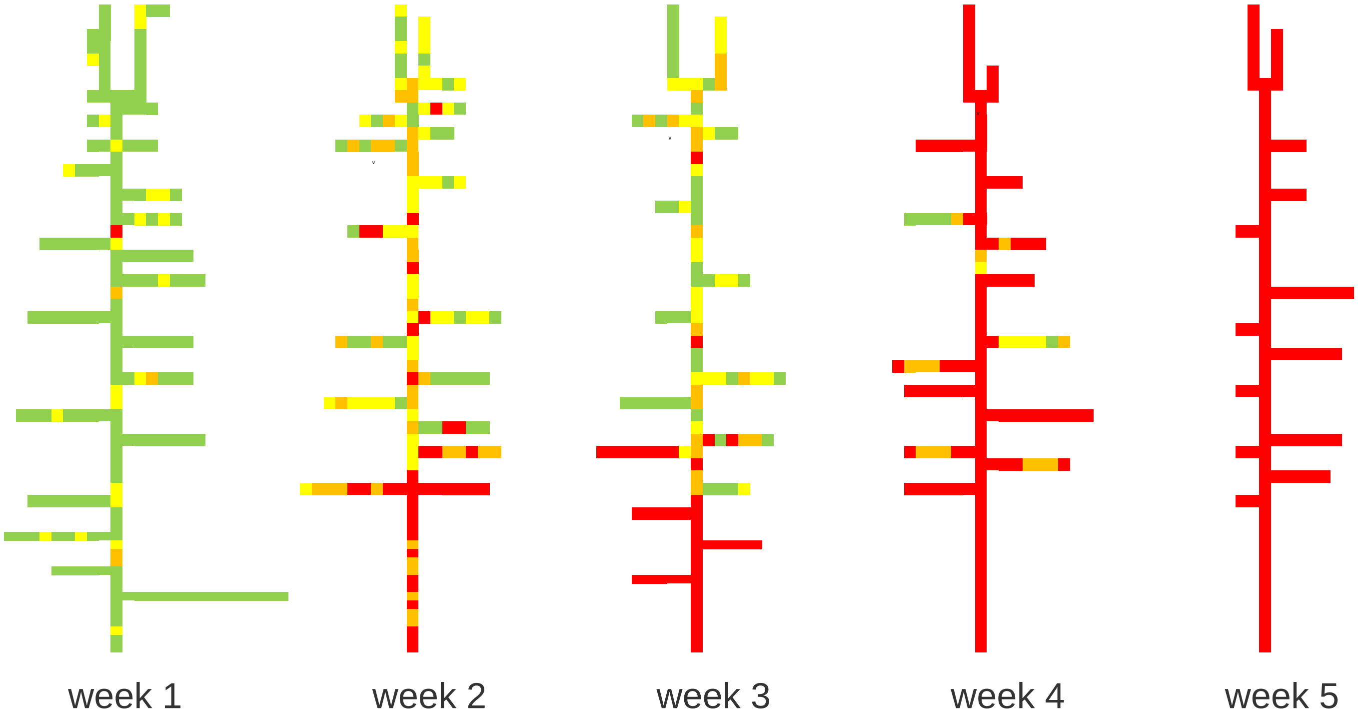
Jessica.Dohmen-Vereijssen@plantandfood.co.nz

Host Interaction: Localisation



What is the most reliable sample for detection?
Is non-destructive sampling possible?

Host Interaction: Localisation



Green = copy number < 1, yellow = copy number 1-100, orange = copy number 101-500, red = copy number > 500.

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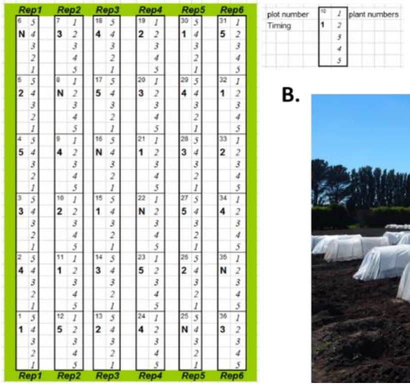
Host Interaction: Localisation

Field trial:

180 plants in 36 cages, up to 21 samples per plant

A.



B.

Stem tissue close to the ground or tuber heel (stolon) end are the most reliable samples for CLso detection.

Leaves and petiole are unreliable and should be avoided.

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