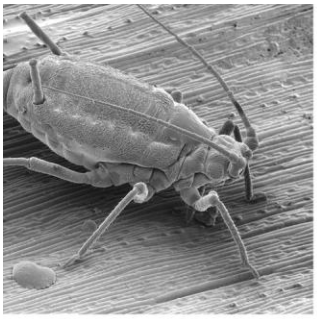
PFR SPTS No. 9766

Final report on growing tolerant cultivars in a Psa environment, VI1296

Currie M, Martin P, Blattmann M, Gordon B, Patterson K.

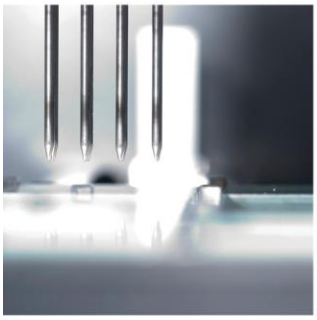
March 2014





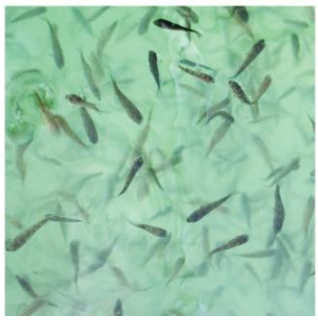
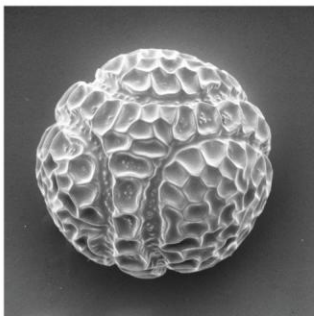










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Executive summary

Final report on growing tolerant cultivars in a Psa environment, VI1296

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Plant & Food Research: [1]Auckland; [2]Te Puke; [3]Kerikeri

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The advent of *Pseudomonas syringae* pv*. actinidiae* (Psa) in kiwifruit orchards has radically changed the way we need to think about kiwifruit growing practices to enable vines a greater chance of survival when challenged with the virulent strain of Psa (Psa-V). Vine structures in New Zealand have usually had a single trunk with one or two leaders as the primary framework upon which to carry the fruiting structure. Secondary infections of Psa-V in a leader, however, can have a major effect on vine productivity, with substantial loss of fruiting canopy beyond the canker if leaders need to be removed.

In order to prevent catastrophic loss of productive canopy area when establishing top-worked kiwifruit vines exposed to Psa-V, we tested two methods of producing four-leader vines. Multi-leader trials with the new cultivars *Actinidia chinensis* 'Zesy002' (commonly known as Gold3), 'Zesy003' (commonly known as Gold9), *A. deliciosa x A. chinensis* 'Zesh004' (commonly known as Green14), an *A. chinensis* breeding selection, an *A. deliciosa* breeding selection, and the standard cultivar *A. deliciosa* 'Hayward', grafted to mature *A. delicosa* 'Bruno' seedling stumps, have been established. Key findings include:

- Grafting four budsticks into established stumps at Te Puke was a highly effective way of developing four trunks and leaders, and these multiple grafts reduced the risks that cankers had on the developing canopy.
- Grafting two budsticks into established stumps at Kerikeri was less costly, but less effective, as graft failures from individual budsticks made it quite difficult to establish four leaders.
- At Kerikeri, heading back developing trunks only 20 cm below the top wire to stimulate new leader-shoots to develop created a relatively high strain on the new shoots to bend them to a horizontal position after they had developed. This resulted in several breakages, severe cracking and a large bend required on some of the leaders. We recommend that such cuts be made at least 50 cm below the wire and new shoots immediately trained at 30°.
- Four-leader systems should be considered by growers, particularly in orchards where Psa symptoms have been prevalent and where old established trunks are available for re-working.
- On strong trunks being reworked, either four two-bud grafts or two three-bud grafts should be made in vines where a four-leader system is to be established. This will allow a good chance that four buds will grow and develop new trunks and leaders.
- Field observations in the Te Puke trial where Psa-V infection has occurred showed that even within the limited range of cultivars used, there were large differences in apparent susceptibility to developing Psa-V symptoms. For example, the *A. chinensis* breeding selection was much more susceptible than either 'Zesy002' or 'Hayward', and 'Zesy003' was intermediate in apparent susceptibility.

- Symptoms of Psa cankers and dieback should be immediately removed from blocks and susceptible cultivars removed entirely as soon as possible, to reduce the inoculum source in the block and to provide the greatest chance that relatively tolerant cultivars will survive.
- One of the Te Puke trial blocks had a very low incidence of Psa symptoms. We recommend that the reasons for this are investigated further. Possible factors include organic fertility management slowing growth rates and early removal of the highly susceptible cultivars ('Hort16A', 'Bruce' and 'Sparkler') from the block.
- The *A. chinensis* breeding selection appeared to be the most susceptible to developing Psa-V symptoms in this current trial, something that has also been observed in other trials. Because of this, the selection is now being discontinued from further development.
- Loss of a leader or trunk in every second vine with a multi-leader system, as was the case with 'Zesy002' in the Te Puke trial, would lead to a much lower loss of potential productivity than with standard vines which have only one or two trunks and leaders.
- Established four-leader-system vines developed productive canopies, but factors limiting production included graft failures, leader breakages and non-productive area of canopy between leaders. *Actinidia chinensis* cultivars such as 'Zesy002' and 'Zesy003' developed close to full canopies of fruit, while *A. deliciosa* cultivars such as 'Hayward', *A. deliciosa* breeding selection and the hybrid cultivar 'Zesh004' were relatively slow to fill allocated canopy space.

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1 Introduction

1.1 Background

In June 2010, Zespri released three new cultivars for commercial production; 'Zesy002,' commonly known as Gold3; 'Zesy003', commonly known as Gold9; and 'Zesh004', commonly known as Green14. In November of that year, *Pseudomonas syringae* pv. *actinidiae* (Psa) a serious bacterial canker disease of kiwifruit, was found on 'Hort16A' orchards in the Te Puke area. Since then, Psa has spread rapidly throughout the Bay of Plenty and several other regions in New Zealand, resulting in almost 100% losses of 'Hort16A' vines, particularly in the Bay of Plenty region.

Information that was available prior to August 2011 from field trials of clonal plants at Te Puke Research Centre and from trials in Italy, suggested that 'Zesy002', 'Zesy003' and 'Zesh004' could be less susceptible to Psa than 'Hort16A'. Additional information from bioassays conducted in the laboratory of Tony Reglinski, Plant & Food Research, Ruakura, appeared to confirm that although these cultivars could become infected, the progression of symptoms occurred more slowly in these cultivars than in 'Hort16A'.

Although it was too early to declare if any of the new cultivars were tolerant to Psa, reduced susceptibility or slowed progression of Psa bacteria within plants after infection could allow new cultivars to be grown in an environment where they will be exposed to Psa bacterial inoculum, if appropriate protection and cultural management procedures were used. Within the New Zealand Clonal trials programme (NC1102-NC1502), a new approach to managing Psa was being trialled; under the assumption was that any plant showing secondary symptoms might survive, only the symptomatic plant parts were removed and the plant allowed to recover or for symptoms to progress further if the plant was a susceptible selection.

Knowledge about the feasibility of such an approach is important for the kiwifruit industry, as we expect that Psa will continue to devastate 'Hort16A' plantings in regions where it becomes established. Indeed in the Bay of Plenty this is the case, with little 'Hort16A' remaining in production. Orchardists required evidence on strategies that can be used on new cultivars that have been introduced to replace 'Hort16A' and that will be introduced for new market niches in the future. For this reason, this project was initiated, but with the understanding that the cultivars chosen may not necessarily be those ultimately used as tolerant cultivars in such a system commercially.

There is now considerable evidence that cultivars such as 'Zesy002' and 'Zesh004' are significantly less susceptible to Psa-V than 'Hort16A', on the basis of numbers of surviving plants and those displaying secondary symptoms such as dieback, cankers and bacterial ooze in New Zealand and Italian trial blocks. However, we expect that a combination of tolerant cultivars alongside management systems that focus on delaying and mitigating the impacts of Psa-V will still be required to allow productive and profitable orchards to be maintained.

1.2 Project objectives

The objectives of this project were threefold:

1. Provide evidence of the Psa-V tolerance of the new and potential cultivars in replicated trial designs to supplement the limited numbers of plants in the New Zealand clonal trial blocks (Project NC1202-NC1502)
2. Identify and deploy novel growing systems that would prevent or delay the impact of Psa-V on kiwifruit vines so that productivity can be maintained
3. Allow rapid integration of any new findings from on-orchard research, where technology transfer can be easily delivered in the heart of the Psa-V priority zone.

1.3 Experimental approach

The project comprised the establishment of two new trial blocks in areas where Psa-V was already well established and where Psa-V is likely to be present in the future. Together they provide for short- and medium-term delivery of outcomes.

Grafted plants at the Te Puke Research Centre. These plants, grafted in 2010 (prior to Psa) and 2011 (during a period where significant Psa inoculum was almost certainly present), provide an excellent demonstration of firstly whether newly grafted plants can survive and secondly whether young canopies can survive Psa infection. If they survive, then protection and cultural measures can be deployed to maintain productivity.

Grafted plants at the Kerikeri Research Centre. At the time of establishing the trial, this region was free of Psa, but, as expected, Psa-V has entered the region and is now within c. 1 km of the trial site. Having a resource of established plants in a randomised design is essential for determining the rate of spread, cultivar response, and how best to manage plants in this environment.

It was expected at the outset that some of the plants in these blocks would succumb to Psa-V during or following establishment. Depending on outcomes in particular blocks, it was anticipated that some trial blocks would possibly need to be abandoned and/or be replaced with more tolerant selections or rootstocks. All decisions in relation to replacement selections were made in consultation with the Zespri New Cultivar Development Steering Committee – Stage 2 Clonal Trials.

Diploid cultivars and selections were not included in the first phases of this project, as many of the diploid selections were showing high susceptibility to Psa in clonal trials during the 2010/2011 growing season. Diploid selections such as ‘Hort16A’ were considered, but were already showing relatively high susceptibility in the field in clonal trials so were not included, as it was considered that they could have presented a major inoculum source in the blocks. Long term, it is anticipated that Psa-resistant rootstocks will be identified and then be established and grafted.

2 Materials and Methods

2.1 Establishment of Trial Blocks

2.1.1 Te Puke Research Centre Trial A

In August 2011, mature 'Bruno' seedling rootstocks at the Te Puke Research Centre were cleft grafted with one of six cultivars or breeding selections that were either at the commercial or pre-commercial stage of development (Currie et al. 2012). The stocks were originally planted and grafted to 'Hayward' in 1982 and were cut back to the 'Bruno' stock prior to grafting.
The trial was laid out as a randomised, complete block replicated design, with 12 vines per female selection and five vines per male selection (Figure 1).

- The cultivars 'Zesy002', 'Zesy003', 'Zesh004', 'Hayward' (used as a standard) an *A. chinensis* breeding selection and an *A. deliciosa* breeding selection were grafted in 2011.

- A second *A. chinensis* selection , which was showing few secondary Psa-V symptoms in 2012, was grafted into spare positions in 2012. Only eight spaces were available for the selection in 2012. Data on this selection have not been presented in this report.

- Several potential Psa-V tolerant males were grafted into male rows in August 2012. This included four *Actinidia chinensis* and four *A. deliciosa* selections. The polliniser selections 'M33' and 'Chieftain' were also included as standards. The aim of this was to both provide pollinisers for the females and to extend the understanding of Psa susceptibility of these males.

The 'Hayward' scions and 'Bruno' stumps used were visibly free of Psa-V secondary cankers at grafting but were not directly tested for Psa infection. Budwood of the cultivars and breeding selections was sourced from Kerikeri Research Centre during winter 2011. At this time, the Kerikeri Research Centre and Kerikeri district were Psa-V negative. Four grafts per stump were made using standard cleft grafts but with budsticks slightly offset from the normal north-south axis line (Figure 2). The grafting procedure necessitated splitting the stumps twice to enable four budsticks to be oriented with sufficient space between them to allow for future leader expansion. Buds were positioned to enable the new shoots to grow up to support wires without direct contact with each other and then in a north- or south-facing direction.

Canopy support wires were repositioned. The single centre wire was removed and two wires c. 1 m apart were placed either side of the original centre wire. Pairs of strings were used to train new shoots up to the support wires and subsequently upwards at an angle c. 30º from horizontal to encourage good leader development. New leaders were brought down to a horizontal position in January, but relatively few new fruiting canes developed in the first growing season. The focus in the first season was on the establishment of new canopies.

Plants were trained with four stems and leaders (Figure 3). A key objective was the ability to remove infected wood immediately without catastrophic loss of productivity. The physical separation of leaders was intended to reduce the chance that infections on one leader would infect the adjacent leader and allow leaders to be managed effectively, with a 'spur' zone of short, terminated cropping wood only between the leaders (Figure 4, Figure 5).

Plants were monitored every two weeks from budbreak until midsummer, then monthly for secondary symptoms of Psa-V such as cankers, bacterial ooze and dieback. As soon as a secondary symptom was detected, the plant part with the symptom was removed to prevent

bacteria spreading throughout the plant. The position of the cuts from the symptom was standardised at 30 cm below the symptom (Figure 6).

Protection of at-risk plant parts was a significant focus. Tools were cleaned and sterilised according to KVH best practice recommendations and all pruning cuts were protected with Greenseal™.

A protectant spray programme was used to minimise the number of infections in Psa-V-positive regions. Sprays were based on KVH best practice recommendations in 2011/12.

Te Puke Research Centre Trial A

Completely randomised block design, grafted 25/8/11 and 15/8/12

	6	7	8	9	10	11	12	13	14	15	
1	G14-11										1
2	Hay-11	ADM-12	G9-11	M33-12	G14-11	ADM-12	Hay-11	Ch-12	G14-12	ADM-12	2
3	AC2-12		AD1-11		G3-11		AC1-11		G14-12		3
4	G9-11	ADM-12	G14-11	M33-12	AC1-11	ACM-12		ADM-12	G14-12	ADM-12	4
5	AC1-11		G3-11		Hay-11		G9-11		G14-12		5
6	AD1-11	ACM-12	Hay-11	ADM-12	AD1-11	ADM-12	G14-11	ACM-12	G14-12	ADM-12	6
7	G3-11		AC1-11		G9-11		G3-11		G14-12		7
8	G9-11	ACM-12	AC2-12	ACM-12	AD1-11	ADM-12	AD1-11	ADM-12	G14-12	ACM-12	8
9	AC2-12		G3-11		Hay-11		AD1-11		G14-12		9
10	G3-11	M33-12	G9-11	ACM-12	G3-11	M33-12	Hay-11	Ch-12	G14-12	ADM-12	10
11	AD1-11		AC1-11		G14-11		AC1-11		G14-12		11
12	G14-11	ADM-12	Hay-11	Ch-12	G9-11	ACM-12	G9-11	ADM-12	G14-12	Ch-12	12
13	AC1-11		AD1-11		AC1-11		G3-11		G14-12		13
14	Hay-11	Ch-12	G14-11	ACM-12	AC2-12	ADM-12	G14-11	ADM-12	G14-12	ADM-12	14
15	G3-11		Hay-11		Hay-11		G3-11		G14-12		15
16	AC2-12	ACM-12	AD1-11	ACM-12	G9-11	ACM-12	AC2-12	ACM-12	G14-12	ACM-12	16
17	Hay-11		G9-11		AD1-11		AC1-11		G14-12		17
18	G9-11	M33-12	G3-11	ACM-12	G3-11	ACM-12	G14-11	ADM-12	G14-12	ADM-12	18
19	AC1-11		G14-11		AC1-11		AC2-12		G14-12		19
20	AD1-11	ADM-12	AC1-11	ACM-12	x	ACM-12	G9-11	ACM-12	G14-12	ACM-12	20
21	G14-11		AC2-12		G14-11		Hay-11		G14-12		21
	6	7	8	9	10	11	12	13	14	15	

Planted	1981	block is 0.38 ha
Rootstock	Bruno seedling	
Spacing	6m in row, 3m between row	
Males	various, trained as 1m wide strip male	

Figure 1. Plan for Te Puke Research Centre trial block A for kiwifruit selections grafted in 2011 (-11) and 2012 (-12). Female selections include G3 = *Actinidia chinensis* 'Zesy002', G9 = 'Zesy003', AC1 = *A. chinensis* female breeding selection, AD1 = *A. deliciosa* female breeding selection, G14 = 'Zesh004', AC2 = second *A. chinensis* female breeding selection, Hay = *A. deliciosa* 'Hayward'. Male selections include four *Actinidia deliciosa* selections (ADM), four *A. chinensis* selections as well as standard cultivars *A. deliciosa* Ch = 'Chieftain' and the *A. chinensis* 'M33'

Figure 2. Orientation of four bud sticks cleft grafted to a mature *Actinidia deliciosa* 'Bruno' seedling stump, Te Puke Research Centre, August 2011. Note the need to separate the budsticks sufficiently to allow for subsequent leader growth.

Figure 3. Training of four trunks from four budsticks grafted to mature *Actinidia deliciosa* 'Bruno' seedling stumps at Te Puke Research Centre. 2011-2012 growing season.

Figure 4. Typical kiwifruit vine showing the established multi-leader structure and stringed fruiting canes in the second growing season, March 2013. Note how the trunks are physically separated to reduce the likelihood of cross infection.

Figure 5. Four-leader system developing from a single grafted kiwifruit scion at Kerikeri Research Centre in March 2013.

Figure 6. Developing leader on an *Actinidia chinensis* 'Zesy003' (Gold9) kiwifruit plant at Te Puke Research Centre that had been cut back to 30 cm below a canker. The position was tagged on 23 January 2013 so the progression of symptoms could be observed. New symptoms could be seen on the base of a fruiting shoot (see arrow) within one month.

2.1.2 Te Puke Research Centre Trial B

In July 2010, mature clonal 'Hayward' rootstocks at the Te Puke Research Centre were grafted with female and appropriate male cultivars. The timing of this grafting was just prior to the appearance of Psa-V in the Te Puke district. The trial was laid out as a randomised complete block design with six tree vine plots (18 plants per female cultivar, Figure 7). These included:

- Five female cultivars ('Zesy002', 'Zesy003', 'Zesh004', 'Hort16A' and 'Hayward')
- Six male cultivars ('Bruce', 'Sparkler', 'M91', 'M33', 'King' and 'Chieftain').

Following the initial decision on cultivars, it became apparent that 'Hort16A' and the diploid males 'Bruce' and 'Sparkler' would potentially become major sources of Psa-V inoculum because of their high susceptibility to this disease. Indeed the strategy at the Te Puke Research Centre at the time was to remove or severely prune vines with secondary infections of Psa-V. Hence a decision was taken to remove these cultivars pro-actively in November 2011 and replace them with other selections to reduce infection pressure within the block, and to meet KVH requirements regarding infected vines.

Subsequent development of canopies on the vines in the block has been relatively slow, possibly associated with the organic management. However, vines have now established full canopies and are producing crops of fruit. The block has been regularly monitored for development of Psa-V symptoms, but the dry summer of 2013 may have retarded any rapid progress.

Te Puke Research Centre Trial B

Bay	Pos	12	11	10	9	8	7	6	5	4	3	2	1	0	Bay	Pos
17	a	M91-10	G3-10	Ch-10	Hay-10	M33-10	G9-10	M91-10	G14-10			M91-10	G14-10		17	a
16	a	M33-10	G3-10	Sp-10	Hay-10	Ch-10	G9-10	M33-10	G14-10	M33-10	Hay-10	Ch-10	G14-10		16	a
15	a	M91-10	G3-10	Ch-10	Hay-10	M91-10	G9-10	M91-10	G14-10	Ch-10	Hay-10	M33-10	G14-10		15	a
14	a	M33-10	G3-10	Sp-10	Hay-10	Ch-10	G9-10	M33-10	G14-10	M91-10	Hay-10	Ch-10	G14-10		14	a
13	a	M91-10	G14-10	M33-10	G3-10	Sp-10	16A-10	M91-10	G3-10	Br-10	16A-10	M33-10	G9-10		13	a
12	a	M33-10	G14-10	M91-10	G3-10	M33-10	16A-10	Br-10	G3-10	M91-10	16A-10	Br-10	G9-10		12	a
11	a	M91-10	G14-10	M33-10	G3-10	Br-10	16A-10	M33-10	G3-10	Sp-10	16A-10	M91-10	G9-10		11	a
10	a	M33-10	G9-10	M91-10	G9-10	M33-10	G14-10	Kg-10	Hay-10	M33-10	G14-10		Hay-10		10	a
9	a	M91-10	G9-10	M33-10	G9-10	M91-10	G14-10	Ch-10	Hay-10	Ch-10	G14-10	M91-10	Hay-10		9	a
8	a	M33-10	G9-10	M91-10	G9-10	M33-10	G14-10	Kg-10	Hay-10	M91-10	G14-10	Ch-10	Hay-10	Ch-10	8	a
7	a	Ch-10	Hay-10	Br-10	16A-10	M91-10	G3-10	Br-10	16A-10	M91-10	G9-10		G3-10	M33-10	7	a
6	a	Ch-10	Hay-10	Ch-10	16A-10	Sp-10	G3-10	M33-10	16A-10	Sp-10	G9-10			M91-10	6	a
5	a	Ch-10	Hay-10	Br-10	16A-10	M33-10	G3-10	Sp-10	16A-10	M33-10	G9-10		G3-10	M33-10	5	a
4	a	Br-10	16A-10	M91-10	G14-10	Kg-10	Hay-10	M91-10	G9-10	M91-10	G3-10	M33-10	16A-10	Br-10	4	a
3	a	Sp-10	16A-10	M33-10	G14-10	M91-10	Hay-10	Ch-10	G9-10	M33-10	G3-10	Sp-10	16A-10	Sp-10	3	a
2	a	Br-10	16A-10	M91-10	G14-10	Ch-10	Hay-10	M33-10	G9-10	M91-10	G3-10	M91-10	16A-10	Br-10	2	a
1	a	Sp-10	16A-10	Br-10	G14-10	M33-10	Hay-10	Ch-10	G9-10	M33-10	G3-10	Br-10	16A-10	Sp-10	1	a

N

Key		
Item	**ID**	**Number of plants**
16A	Hort16A existing rootstock	20
G3	Gold 3 existing rootstock	19
G9	Gold 9 existing rootstock	20
Hay	Hayward existing rootstock	20
G14	Green 14 existing rootstock	21
Br	Bruce	11
Sp	Sparkler	10
M91	M91	24
M33	M33	25
Ch	Ch	15
Kg	Kg	3
???	Diseased, Armillaria	
???	Young replant	
????	Missing (diseased plant removed), needs replant	

Notes 29 July 2010

1/6	diseased plant
1/8	Young replant
2/5	diseased plant
2/6	Missing
2/7	Missing
2/8	Young plant, small but graftable
2/9	Young plant, small but graftable
2/10	Missing
3/17	diseased plant
4/17	diseased plant

All plants in rows 1-4 had been sluiced to prevent Armillaria spread. Armillaria considered unlikely to affect young replants

Existing rootstocks at Northern end of bay, c. 0.5m from post, except row 5, where they are in middle of bay

Figure 7. Plan for Te Puke Research Centre trial block B for selections grafted in 2010 (-10) and 2012 (-12). Female selections include *G3*, Gold3 = *Actinidia chinensis* 'Zesy002', *G9*, Gold9 = *Actinidia chinensis* ' 'Zesy003', G14, Green14 = 'Zesh004', Hay = *A. deliciosa* 'Hayward'. 16A = 'Hort16A', Br = 'Bruce' and Sp = 'Sparkler' have subsequently been removed. Male selections include hexaploid *A. deliciosa* Ch = 'Chieftain', tetraploid *A. chinensis* M33 and M91.

2.1.3 Kerikeri Research Centre Trial Block

In August 2011, mature 'Bruno' seedling rootstocks at the Kerikeri Research Centre were worked over to six female cultivars and breeding selections (Figure 8). This block was set up on the expectation that Psa-V could reach the region in future. A randomised complete block design with four x two-vine plots (eight plants total per female cultivar) was established. The existing male cultivars 'Sparkler', 'Meteor' and 'Bruce' (grafted in 2002) were left in place in the adjacent strip male rows.

- The female cultivars 'Zesy002', 'Zesy003', 'Zesh004', 'Hayward' (used as a standard), the *A. chinensis* breeding selection and the *A. deliciosa* breeding selection were grafted.

- The male cultivars were 'Sparkler', 'Meteor', and 'Bruce' and were already established in the block, but will need to be re-grafted with the new prospective male selections.

The stumps in the Kerikeri block were cleft grafted and two budsticks were used per stump as there was insufficient budwood available from the Kerikeri Research Centre to make four grafts per stump. Budwood was ostensibly Psa-free, as Psa-V had not been detected in plantings at the Centre at the time of budwood collection. The new shoot from each graft was then cut c. 20 cm below the plane of the support wires. This allowed the potential for two strong shoots to grow out and be trained as above. The original centre wire was left in place and stringing was used to encourage good leader growth in the north and south directions along the existing “first wires”, which were spaced at distances of 35 cm from the centre wire. Stringing was also used to encourage good fruiting cane development in the subsequent growing season.

Plants in the trial were routinely monitored for Psa-V symptoms as above. Although Psa-V has been confirmed in the district, no evidence of infection by Psa-V at this orchard has been found to date.

Wound protection was carried out with Greenseal™ and a copper-based protectant spray programme using KVH best practice guidelines was strictly followed.

Kerikeri trial block NORTH

		Row ->					
Bay	Pos	8	9	10	11	Bay	Pos
1	a		Me-02	Hay-11	Me-02	1	a
	b	G3-11		Hay-11			b
2	a	AC1-11	Sp-02	AC1-11	Sp-02	2	a
	b	AC1-11		AC1-11			b
3	a	Hay-11	Br-02	G9-11	Br-02	3	a
	b	Hay-11		G9-11			b
4	a	G14-11	Me-02	G14-11	Me-02	4	a
	b	G14-11		G14-11			b
5	a	AD1-11	Sp-02	G3-11	Sp-02	5	a
	b	AD1-11		G3-11			b
6	a	G9-11	Br-02	AD1-11	Br-02	6	a
	b	G9-11		AD1-11			b
7	a	AD1-11	Me-02	G14-11	Me-02	7	a
	b	AD1-11		G14-11			b
8	a	G3-11	Sp-02	AC1-11	Sp-02	8	a
	b	G3-11		AC1-11			b
9	a	AC1-11	Br-02	AD1-11	Br-02	9	a
	b	AC1-11		AD1-11			b
10	a	G14-11	Me-02	Hay-11	Me-02	10	a
	b	G14-11		Hay-11			b
11	a	G9-11	Sp-02	G9-11	Sp-02	11	a
	b	G9-11		G9-11			b
12	a	Hay-11	Br-02	G3-11	Br-02	12	a
	b	Hay-11		G3-11			b
13	a	AC1-11	Me-02	G14-11	Me-02	13	a
	b	AC1-11		G14-11			b
14	a	AD1-11	Sp-02	Hay-11	Sp-02	14	a
	b	AD1-11		Hay-11			b
15	a	G3-11	Br-02	G3-11	Br-02	15	a
	b	G3-11		G3-11			b
16	a	G14-11	Me-02	G9-11	Me-02	16	a
	b	G14-11		G9-11			b
17	a	Hay-11	Sp-02		Sp-02	17	a
	b	Hay-11		AC1-11			b
18	a		Br-02		Br-02	18	a
	b			AD1-11			b

Canopy ha = 0.356

Block is 125m long, 40m wide

Figure 8. Plan for Kerikeri Research Centre trial block grafted in 2011 (-11). (Female selections include *G3* = *Actinidia chinensis* 'Zesy002' *G9* = 'Zesy003', AC1 = *A. chinensis* breeding selection, AD1 = *A. deliciosa* breeding selection, G14 = 'Zesh004', Hay = *A. deliciosa* 'Hayward'. Existing 2002 grafted diploid *A. chinensis* male selections Me ='Meteor'', Sp = 'Sparkler' and Br='Bruce' were due to be re-grafted to new males in 2012, but were delayed because of a shortage of budwood).

2.2 Evaluation of canopy development

At Te Puke trial block A and the Kerikeri trial block, each vine was visually assessed for the number of surviving grafts, full leaders and percentage of the allocated canopy filled in March 2014.

2.3 Evaluation of field tolerance to Psa-V infection

A field scoring system for Psa-V infection was developed to weight the consequences of symptoms occurring on different parts of the plants. The weighting was designed to reflect the effects that the symptom would have had on the cropping ability of the plant.

Individual plants where symptoms had been observed occurring on the permanent structure of wood older than one-year-old (trunks and leaders) were given a higher rating (50%) than those occurring on one-year-old canes (25%) or on current season shoots (12.5%). The highest rating of 100% was given to plants where the symptom was so severe as to require the entire scion to be removed.

This scoring system therefore takes account of the “significance” to vine productivity of a canker on a trunk, which is potentially much more debilitating than a canker on a single cane. For the purpose of scoring, trunks were defined as vine parts between the graft union with the rootstock and the canopy plane, while leaders were defined as the permanent structures oriented horizontally.

A vine requiring all the grafted scions to be removed because of infection will be assigned a score of 100 as no crop would be possible, whereas a plant where no secondary symptoms have been observed will have a field score of zero as cropping would not be directly affected at all.

In order to determine the average field score, the individual field scores of each replicate plant were averaged. For example, for a cultivar with 12 replicate plants, where four of the scions had been completely removed (100%), three had been found with trunk/leader cankers (50%), four had secondary symptoms on one-year-old canes only (25%) and one was free of secondary plant symptoms (0%), would have a field Psa score of 54.

3 Results and Discussion

3.1 Graft success and leader development

3.1.1 Te Puke Research Centre Trial Block A

In the Te Puke trial block, grafting of four budsticks on each 'Bruno' stump was highly successful, for most of the cultivars. All grafted stumps developed at least one successful graft and 95% of the budsticks established good initial growth and carried on to produce fruiting canopies (Table 1, Table 2). Other findings included:

- A slightly reduced graft success was evident with the selection *A. chinensis* breeding selection, where only 79% of the budsticks took successfully. It is possible that the reduced success with this selection was due to a higher susceptibility to Psa-V infection (Figure 9, also see section 3.2 on page 22). However, by March 2014, almost all the *A. chinensis* breeding selection grafts had succumbed to Psa infection and had been removed down to the rootstock. Only ¼ of the *A. chinensis* breeding selection vines had a scion remaining and these vines had only one or two grafts surviving (Table 2).
- For 'Hayward', 'Zesh004', 'Zesy002' and *A. deliciosa* breeding selection, between three and four of the grafts produced full leaders on average during the 2011/12 growing season (Table 1). However, 'Zesy003' originally had fewer leaders per plant, mainly because of Psa-V infection, which required part or all of the leaders to be removed during the growing season as symptoms developed. In the last 12 months, new leaders have been developed and almost all the Hayward', 'Zesh004', 'Zesy002', the *A. deliciosa* breeding selection and 'Zesy003' plants had four fully developed leaders (Table 2).
- The four-trunk and leader system developed well (Figure 4, Figure 10). Growing shoots were trained up strings to the top wire and then up a leader string at an angle of c. 30°. New leaders were brought down to a horizontal position in January, but relatively few new fruiting canes had developed in the first two seasons. 'Hayward', the *A. deliciosa* breeding selection and 'Zesh004' were still slow to develop a full canopy. However, by 2014, 'Zesy002' and 'Zesy003' had developed close to 100% full canopy (Table 2) and all selections except 'Zesy003' were cropping reasonable fruit numbers.

Table 1. *Actinidia* graft success and leader development in the Te Puke Research Centre Trial Block A by June 2013. Vines are likely to have been exposed to *Pseudomonas syringae* pv. *actinidiae* (Psa-V) bacteria prior to and after grafting.

Selection/ cultivar	Vines grafted	Proportion of vines with at least one successful graft (%)	Average graft success of individual budsticks (%)	Average number of leaders developed (no. per vine)[1]
'Hayward'	12	100	98	$3.8_{\pm 0.1}$
'Zesh004'	12	100	98	$3.8_{\pm 0.2}$
A. deliciosa breeding selection	11	100	100	$3.6_{\pm 0.2}$
'Zesy002'	12	100	100	$3.8_{\pm 0.1}$
'Zesy003'	12	100	96	$2.6_{\pm 0.3}$
A. chinensis breeding selection	12	100	79	$2.4_{\pm 0.4}$
Average		100	95	$3.3_{\pm 0.1}$

[1] ± Standard Error

Table 2. *Actinidia* graft, leader and canopy survival in the Te Puke Research Centre Trial Block A by March 2014. Vines were exposed to *Pseudomonas syringae* pv. *actinidiae* (Psa-V) bacteria prior to and after grafting.

Selection/ cultivar	Plants with at least one successful graft remaining (%)	Average number of surviving grafts per plant	Average number of leaders developed per plant	Average Canopy fill %
'Hayward'	100	$4.0_{\pm 0.00}$	$3.9_{\pm 0.08}$	$64_{\pm 4.0}$
'Zesh004'	100	$4.0_{\pm 0.00}$	$4.0_{\pm 0.00}$	$63_{\pm 2.8}$
A. deliciosa breeding selection	100	$3.9_{\pm 0.09}$	$3.9_{\pm 0.09}$	$66_{\pm 4.1}$
'Zesy002'	100	$4.0_{\pm 0.00}$	$4.0_{\pm 0.00}$	$86_{\pm 2.6}$
'Zesy003'	100	$3.8_{\pm 0.13}$	$3.8_{\pm 0.11}$	$83_{\pm 3.6}$
A. chinensis breeding selection	25	$0.6_{\pm 0.36}$	$0.6_{\pm 0.31}$	$10_{\pm 5.4}$
Average	88	$3.4_{\pm 0.16}$	$3.4_{\pm 0.16}$	$62_{\pm 3.4}$

[1] ± Standard Error

Figure 9. Recovery of an *Actinidia chinensis* selection at Te Puke during the dry summer of 2013 that was severely affected by *Pseudomonas syringae* pv*. actinidiae* (Psa-V) during the 2011/12 growing season. Note that three of the four original grafts had died.

Figure 10. Development of *Actinidia* canopies at Te Puke Research Centre Trial block A March 2014. Top left: Four successful 'Zesh004' grafts, Top right: Four trunks and leaders of 'Zesh004' with good separation, Centre left: 'Hayward' canopy well developed on left, but with little fruiting wood developed between the leaders, Centre right: 'Zesy002' canopy with two well developed leaders (arrows), Bottom left: *A. chinensis* breeding selection with two surviving grafts, Bottom right: 'Zesy003' leader and fruit after having lost a portion to *Pseudomonas syringae* pv*. actinidiae* (Psa-V).

3.1.2 Te Puke Research Centre Trial Block B

At the time of grafting, the Psa tolerance and cropping ability of 'Zesy002', 'Zesy003' and 'Zesh004' were still far from clear. The monitoring of Psa field susceptibility from block 23 in 2011 and 2012 has been useful in allowing an increased plant and block numbers to be recorded.

In 2013, the widespread grafting of these cultivars elsewhere and the inclusion of 'Zesy002' and 'Zesh004' as standards in new clonal trials has improved the understanding of their responses to Psa. This block developed low incidence of Psa symptoms, which have been discussed further in section 3.2.

3.1.3 Kerikeri Research Centre Trial Block

In the Kerikeri Trial Block, where two budsticks were grafted into each 'Bruno' stump in the standard way, overall graft success on a per vine basis was very high, with an average of 99% of vines grafted having at least one successful graft (Table 3). In fact, only one 'Hayward' plant had both grafts fail. However, grafted budsticks had a lower success when assessed individually. Although the average individual success was 85% across all cultivars, only 68% of the *A. deliciosa* breeding selection budsticks produced a successful graft (Table 3).

The variability of individual budsticks to develop successfully limited the development of a four-leader system in the first year. Where there was only a single successful graft, it was sometimes not possible to develop initially more than two new leaders (Figure 5). For example, the *A. deliciosa* breeding selection was compromised by the low budstick success rate and developed only one leader in every two plants. In contrast, 'Zesh004', 'Zesy002', 'Zesy003' and the *A. chinensis* breeding selection all initially developed between three and four leaders per plant on average.

By March 2014, a high proportion of vines had developed four leaders, although 'Hayward' and *A. deliciosa* breeding selection had only produced c. three leaders per vine on average (Table 4). 'Hayward', the *A. deliciosa* breeding selection and 'Zesh004' were slow to develop a full canopy (Figure 12). In contrast, 'Zesy002', the *A. chinensis* breeding selection and 'Zesy003' had developed close to a full canopy (Table 4, Figure 12, Figure 13). The contrast between the ability of the *A. chinensis* breeding selection at Kerikeri to grow a full canopy in the absence of Psa (Table 4) and its inability at Te Puke in the presence of Psa (Table 2) is considerable.

A summary of key issues observed with the four-leader system at Kerikeri:

- Where one of the two grafts failed, it was often difficult to develop four leaders with the remaining budstick. In particular, where there was only one surviving budstick, growing four leaders appears to have reduced the strength of each new leader being developed.

- Cutting the trunk only 20 cm below the top wire created a relatively high strain on the new shoots to bend them to a horizontal position after they had developed. This resulted in several breakages, severe cracking and a large bend required on some of the leaders (Figure 11), none of which was desirable.

- Leaders were crossed over at the top wire to avoid breakage of the young shoots if they had been trained apart. However, this resulted in leaders rubbing against each other, which would become an entry point for infection in a Psa-V environment (Figure 12).

- In the future, if a bacterial canker was observed on one of the two trunks, it could require the removal of two complete leaders. When there was a single graft, the entire canopy may need to be removed.

Figure 11. Impacts of strain on new *Actinidia* leaders, caused by the tight angle required to bring shoots down to the leader wire at the Kerikeri trial block. Top: new leader broken out of its socket (arrow), Bottom: damage due to severely cracking leader bent to horizontal (arrow).

Table 3. *Actinidia* graft success and leader development in the Kerikeri Research Centre trial by June 2013, where vines were not exposed to *Pseudomonas syringae* pv. *actinidiae* (Psa-V) bacteria.

Selection/ cultivar	Vines grafted	Proportion of vines with at least one successful graft (%)	Average graft success of individual budsticks (%)	Average number of leaders developed (no. per vine)[1]
'Hayward'	12	92	86	$1.9_{\pm 0.4}$
'Zesh004'	12	100	96	$3.1_{\pm 0.3}$
A. deliciosa breeding selection	11	100	68	$0.4_{\pm 0.2}$
'Zesy002'	11	100	82	$3.5_{\pm 0.2}$
'Zesy003'	10	100	85	$3.3_{\pm 0.3}$
A. chinensis breeding selection	11	100	91	$3.5_{\pm 0.2}$
Average		99	85	$2.6_{\pm 0.2}$

[1] ± Standard Error

Table 4. *Actinidia* graft, leader and canopy survival in the Kerikeri Research Centre trial by March 2014, where vines were not exposed to *Pseudomonas syringae* pv. *actinidiae* (Psa-V) bacteria.

Selection/ cultivar	Plants with at least one successful graft remaining (%)	Average number of surviving grafts per plant	Average number of leaders developed per plant	Average Canopy fill %
'Hayward'	100	$1.6_{\pm 0.15}$	$3.2_{\pm 0.26}$	$50_{\pm 3.8}$
'Zesh004'	100	$1.9_{\pm 0.08}$	$3.5_{\pm 0.19}$	$63_{\pm 3.8}$
A. deliciosa breeding selection	100	$1.1_{\pm 0.09}$	$2.7_{\pm 0.30}$	$45_{\pm 4.5}$
'Zesy002'	100	$1.5_{\pm 0.16}$	$3.6_{\pm 0.15}$	$80_{\pm 3.7}$
'Zesy003'	100	$1.6_{\pm 0.16}$	$3.6_{\pm 0.16}$	$90_{\pm 3.6}$
A. chinensis breeding selection	100	$1.7_{\pm 0.14}$	$3.4_{\pm 0.19}$	$80_{\pm 4.7}$
Average	100	$1.6_{\pm 0.06}$	$3.3_{\pm 0.09}$	$68_{\pm 2.6}$

[1] ± Standard Error

Figure 12. Development of *Actinidia* canopy at the Kerikeri trial block by March 2014. Top left: *A. deliciosa* 'Hayward' leader structure from two grafts, Top right: 'Hayward' fruiting canopy, Centre left: 'Zesh004' leader structure from a single graft, Centre right: 'Zesh004' fruiting canopy, Bottom left: 'Zesy002' fruiting canopy, Bottom right: *A. chinensis* breeding selection fruiting canopy.

Figure 13. Development of canopy on *Actinidia chinensis* 'Zesy003' at the Kerikeri trial block by March 2014. Top left: two successful grafts on a plant, Top right: arrangement of successfully trained leaders from two grafts – no touching leaders, Centre left: leaders touching – potential future *Pseudomonas syringae* pv. *actinidiae* (Psa-V) risk, Centre right: fruiting canopy, Bottom left: fruiting canopy, Bottom right: fruiting canopy.

3.2 Psa – consequences of infection

The incidences of Psa-V infection between the different cultivars clearly demonstrate how the multi-leader system can lessen the risks of a trunk or leader infection (Table 5):

- For example, in the Te Puke block A trial, the *A. chinensis* breeding selection initially lost an average of one leader on every vine, which would have been catastrophic in a standard

commercial orchard, resulting in a 50% loss of canopy. Although a four-leader system was insufficient to save this highly susceptible selection (Table 5), some of the *A. chinensis* breeding selection vines in the block have managed to survive for almost three years and are producing fruit in 2014.

- In contrast, 'Zesy002' only lost a developing leader on every second vine on average in Te Puke trial block A, so the loss to productive capacity on a four-leader system would only be c. 12% of the canopy area. While new leaders were being developed, replacement canes from the adjacent leader were used to fill the canopy space, resulting in close to full canopies (Table 2). This provides a significantly improved position for a commercial operation than reduction in potential canopy area. In some cases, we have recently observed multiple grafts on other trial orchards. For example, at a trial block in Pukekohe, we observed up to five grafts per vine, on trunks and suckers. This was allowing a more rapid filling of the canopy and protection against Psa on any of the vines.

The Psa incidence data also demonstrate that there are major differences in the susceptibility of cultivars already available and those still being developed. For example, the *A. chinensis* breeding selection was the most susceptible selection in the Te Puke block A trial, with a Psa field score of 88 out of 100, whereas while 'Zesy003' appeared to be relatively susceptible, with a number of dieback and canker symptoms being observed (Figure 14) and a field score of 41, it had progressed only slightly during the last nine months. Both 'Zesy002' and the *A. deliciosa* breeding selection showed some susceptibility, while 'Zesh004' and 'Hayward' only had minor secondary symptoms, restricted to canes (Table 5). The *A. chinensis* breeding selection appeared to be the most susceptible to developing Psa symptoms in this current trial, something that has also been observed in other trials.

In contrast, the Te Puke block B trial showed extremely low incidences of any secondary Psa symptoms (Table 6). Although the plants were grafted and had begun to establish canopies prior to Psa symptoms being found on the orchard, other plants of these cultivars elsewhere on the orchard, such as within the clonal trials blocks, have developed more symptoms. There are several explanations why this could be the case:

1. Canopy development in this block has been relatively slow, possibly because of the organic management of soil fertility. Although recent soil tests suggested that the soils were in the middle of the recommended ranges for most minerals, including potassium, nitrogen concentrations were relatively low. We can speculate that the reduced growth rates could have allowed developing leaves to be better protected by the copper sprays and/or for the vines to require fewer pruning cuts and the potential for entry of Psa bacteria via these wounds.

2. An alternative hypothesis is that the early removal of 'Hort16A', 'Bruce' and 'Sparkler' left the block with no highly susceptible selections that could act as nearby inoculum sources to re-infect nearby vines consistently. As the management plan included regular monitoring and removal of the (few) secondary symptoms, this may have reduced inoculum sources to a point where few infections occurred.

There are factors other than canopy loss associated with Psa-V infection that could influence cropping ability, such as decline in photosynthetic ability, flower death and fruit losses. The new cultivar development programme is continuing to identify selections where vines can tolerate Psa-V, but the ability of surviving selections to continue cropping is important, so the influence of these other symptoms will become more relevant as more 'tolerant' selections become identified.

Our strategy was to remove secondary symptoms of Psa as soon as they were observed, to try to limit spread and reduce inoculum sources on the vines. The decision to cut c. 30 cm below the lesion was made in the absence of experimental evidence. However, Horner et al. (2013) have since concluded that a strategy of cutting well below lesions was appropriate for 'Hayward' and 'Zesy002' cultivars. In their study, they used a cut position of 40 cm, but also pointed out that the cut position may need to vary depending on factors such as cultivar, wood age and canopy structural considerations. We expect that these factors will need to be fine tuned for individual cultivars, something that is outside the scope of the current trial.

Currently, the occurrence of field symptoms on wood and shoots is being recorded in detail only in clonal trials, and there has been some correlation with results from commercial orchards where breeding selections are trialled or where new cultivars such as ‘Zesy002’, ‘Zesh004’. Field results have the advantage that they replicate how a cultivar is likely to behave in a commercial situation. However, they are prone to differences in environment within and between orchards and between different growing seasons. Because of this, the use of replicated trials and comparison with standard cultivars will become a critical component for their validation.

The Kerikeri trial site does not have any evidence of Psa-V infection at this time. Psa-V has been found on vines in the Kerikeri district within c. 1 km of the trial site and it might be expected that infection could move to the Kerikeri Research Centre site in the future. This will give us the opportunity to observe how these systems work when the plants are established prior to infection.

Table 5. Incidence of secondary symptoms and calculated *Pseudomonas syringae* pv. *actinidiae* (Psa) field score for *Actinidia* plants in the Te Puke Research Centre trial block A to March 2014 (Grafted in 2011, after Psa).

Cultivar[1]	Incidence of secondary symptoms on each plant part (number per plant)					Overall Psa field score (0 to 100)[2]
	Scion removed back to rootstock	Trunks	Leaders	Canes	Shoots	
'Hayward'	nil	nil	nil	$0.1_{\pm 0.08}$	$0.0_{\pm 0.00}$	$2_{\pm 2.1}$
'Zesh004'	nil	nil	nil	$0.1_{\pm 0.08}$	$0.0_{\pm 0.00}$	$2_{\pm 2.1}$
A. deliciosa breeding selection	nil	nil	$0.5_{\pm 0.08}$	$0.6_{\pm 0.11}$	$0.0_{\pm 0.00}$	$18_{\pm 2.1}$
'Zesy002'	nil	nil	$0.5_{\pm 0.12}$	$0.6_{\pm 0.06}$	$0.2_{\pm 0.03}$	$18_{\pm 1.6}$
'Zesy003'	nil	nil	$0.7_{\pm 0.04}$	$0.6_{\pm 0.07}$	$0.5_{\pm 0.06}$	$41_{\pm 1.5}$
A. chinensis breeding selection	$3.5_{\pm 0.08}$	$1.3_{\pm 0.16}$	$1.0_{\pm 0.13}$	$0.1_{\pm 0.02}$	$0.0_{\pm 0.00}$	$88_{\pm 1.9}$

[1] Includes the *A. chinensis* breeding selection and *A. deliciosa* breeding selection.

[2] A field score for Psa has been calculated as a weighted average of the occurrence of symptoms on different parts of the plant. Symptoms occurring on the permanent structure (trunks and leaders) are given a higher rating than those occurring on canes or shoots. A plant where all the grafted scions needed to be removed will have a field score of 100; a plant where no secondary symptoms have been observed will have a field score of 0.

Table 6. Incidence of secondary symptoms and calculated *Pseudomonas syringae* pv. *actinidiae* (Psa-V) field score for *Actinidia* plants in the Te Puke Research Centre trial block B to March 2014 (Grafted in 2010, prior to Psa).

Cultivar	Incidence of secondary symptoms on each plant part (number per plant)					Overall Psa field score (0 to 100)[1]
	Scion removed back to rootstock	Trunks	Leaders	Canes	Shoots	
'Hayward'	nil	nil	nil	nil	nil	0
'Zesh004'	nil	nil	$0.0_{\pm 0.01}$	$0.0_{\pm 0.01}$	$0.0_{\pm 0.01}$	$4_{\pm 0.5}$
'Zesy002'	nil	nil	$0.0_{\pm 0.01}$	$0.1_{\pm 0.01}$	$0.1_{\pm 0.01}$	$5_{\pm 0.5}$
'Zesy003'	nil	nil	nil	$0.6_{\pm 0.04}$	$0.0_{\pm 0.00}$	$9_{\pm 0.6}$
'Chieftain' male	nil	nil	$0.1_{\pm 0.01}$	$0.2_{\pm 0.02}$	$0.0_{\pm 0.00}$	$7_{\pm 0.7}$
M91 male	nil	nil	nil	$0.3_{\pm 0.05}$	$0.1_{\pm 0.01}$	$4_{\pm 0.3}$
M33 male	nil	nil	nil	$0.0_{\pm 0.01}$	$0.0_{\pm 0.00}$	$1_{\pm 0.2}$
'King' male	nil	nil	nil	nil	nil	0

[1] A field score for Psa has been calculated as a weighted average of the occurrence of symptoms on different parts of the plant. Symptoms occurring on the permanent structure (trunks and leaders) are given a higher rating than those occurring on canes or shoots. A plant where all the grafted scions needed to be removed will have a field score of 100; a plant where no secondary symptoms have been observed will have a field score of 0.

Figure 14. Secondary *Pseudomonas syringae* pv. *actinidiae* (Psa-V) symptoms that developed on *Actinidia chinensis* 'Zesy003' in the Te Puke trial block A. Secondary symptoms such as cankers and dieback were removed as soon as they were observed. Top: dieback on a current season shoot, Bottom: Canker on a cane.

4 Conclusions and Recommendations

This is the final report on development of multi-leader growing systems for kiwifruit as a method of managing vines to mitigate the impact of Psa bacterial canker disease. Our main conclusions are:

1. We have demonstrated that a multi-leader system has potential to reduce the consequences of secondary infections in vines significantly. High graft success was obtained following grafting of four budsticks onto older established rootstocks at Te Puke Research Centre, and generally allowed the successful establishment of four leaders.

2. Grafting two budsticks at Kerikeri Research Centre increased the risk that four leaders could not be developed quickly, but was less costly to establish.

3. The consequences for a canker on a leader after grafting two budsticks at Kerikeri would have been the same as for the Te Puke four-graft system, but leaders were often touching, which could increase the risk of rubbing and cross infection. In addition, only one or two trunks were present, resulting in the risk of a catastrophic loss if an infection occurred on that trunk.

4. There were major differences in susceptibility of the cultivars ‘Hayward’, ‘Zesy002’, ‘Zesy003’, and ‘Zesh004’ as well as the *A. chinensis* breeding and *A. deliciosa* breeding selection to the development of Psa-V symptoms at a newly grafted four-leader trial block. The *A. chinensis* breeding selection appeared very susceptible and unsuitable to be grown in a Psa-V environment. However, the dry conditions during the 2012-2013 growing season have allowed even the relatively susceptible *A. chinensis* breeding selection to re-establish some canopy framework.

5. Loss of a leader or trunk in every second vine with a multi-leader system, as was the case with ‘Zesy002’ and 'Zesy003' in this trial, would lead to a much lower loss of potential productivity than with standard vines that only have one or two trunks and leaders. Psa has had very little impact on productivity on these selections at Te Puke trial blocks and vines appear to be highly productive in their third growing season.

6. The very low incidence of Psa symptoms at the Te Puke trial B block is of interest. Possible reasons include the organic soil management system with low inputs of nitrogen fertiliser, which could reduce the growth rate and incidence of pruning, so that copper protectants are more effective, as well as that all known susceptible cultivars were removed early, to reduce inoculum sources.

Recommendations include:

1. Four leader systems should be considered by growers, particularly in orchards where Psa symptoms have been high and where old established trunks are available for re-working.

2. On strong trunks being reworked, either four two-bud grafts or two three-bud grafts should be made in vines where a four-leader system is to be established. This will allow a good chance that four buds will grow and develop new trunks and leaders.

3. If fewer than four stems can be developed because of graft failure or bud termination, the shoot should be headed back at least 50 cm below the leader, to allow multiple lateral buds to re-grow into leaders that do not need to be bent at an extreme angle. Shoots should be immediately trained at c. 30° from vertical, so that they can be gradually turned to horizontal more easily when they are brought down to the leader wire.

4. Symptoms of Psa cankers and dieback should be immediately removed from blocks (Horner et al. 2013) and susceptible cultivars removed entirely as soon as possible, to reduce the inoculum source in the block and provide the greatest chance that relatively tolerant cultivars will survive.

5. The low incidence of Psa symptoms in the Te Puke trial block B should be further investigated to determine why this has occurred.

5 References

Currie M, Martin P, Maxwell E, Astill M, Kashuba P, Seymore S, Carter C, Grierson V, Duffy A, Hunter D, Feng R, White A, Petley M, Maddumage R, Atkinson R 2012. NC1202 – clonal trials 2011 Plant & Food Research Internal Report SPTS 7171. Final report to Zespri on Project NC13202. Pp. 66 pp.

Horner I, Manning M, Casonato S 2013. Psa intervention: cauterising versus pruning Confidential report to Zespri Group Limited on project VI1353. SPTS No 9381. Pp. 14.

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