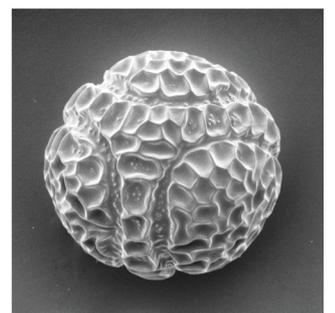
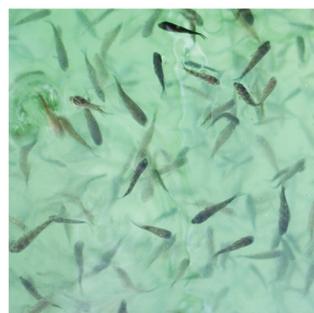
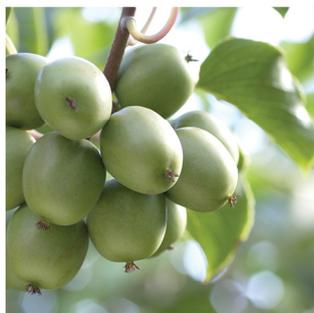
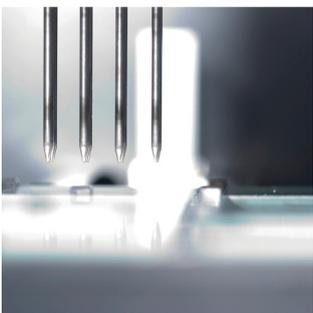
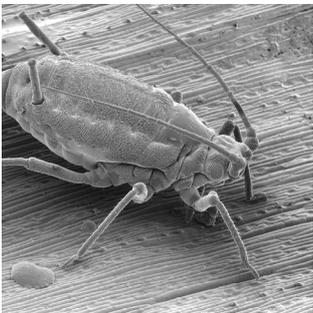


PFR SPTS No 8596

Psa Progression and Intervention

Horner I, Manning M, Casonato S

June 2013



Confidential Report for:

Zespri Group Ltd
Project VI 1353

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PUBLICATION DATA

Horner I, Manning M, Casonato S. June 2013. Psa Progression and Intervention. A report prepared for: Zespri Group Ltd, Project No V11353. Plant & Food Research data: Milestone No. 53291. Contract No. 29518. Job code: P/345087/01. SPTS No. 8596.

Report approved by:

Ian Horner
Scientist/Researcher, Pathogen Biology and Ecology
Date: June 2013

Bob Fullerton
Science Group Leader, Pathology & Applied Mycology
Date: June 2013

Authors:

Horner I
Plant & Food Research, Havelock North

Manning M,
Plant & Food Research, Mt Albert

Casonato S
Plant & Food Research, Te Puke

This report has been prepared by The New Zealand Institute for Plant & Food Research Limited (Plant & Food Research).
Head Office: 120 Mt Albert Road, Sandringham, Auckland 1025, New Zealand, Tel: +64 9 925 7000, Fax: +64 9 925 7001.
www.plantandfood.co.nz

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For further information please contact:

Ian Horner
The New Zealand Institute for Plant & Food Research Ltd
Plant & Food Research Hawkes Bay
Cnr Crosses and St Georges Roads
Havelock North 4130
NEW ZEALAND
Tel: +64-6-975 8925
Fax: +64-6-975 8881
Email: ian.horner@plantandfood.co.nz

1 Key question and aim

This project aims to determine long-term symptom progression in 'Hayward' and 'Zesy002' (Gold3) orchards, relate this progression to orchard management practices, and determine whether practices such as cauterising and partial cutting reduce the long-term impact of Psa in 'Hayward' and Gold3 vines.

2 Methodology

2.1 Progression:

- This is a continuation of a previous detailed study (VI1175/6.1) of progression of Psa in 'Hayward' and Gold3 orchards.
- Regular monthly visits were made to the same orchards and vines that were monitored in previous seasons.
- Assessments of leaf spotting and secondary symptoms were made at each visit, with emphasis on progression of secondary symptoms.
- All secondary symptoms were marked and their advance was measured at each five-weekly assessment from September 2012 to May 2013. A final assessment will be made in September/October 2013.

2.2 Intervention:

- The experiment is being carried out on two 'Hayward' and one Gold 3 orchard, all of which showed moderate to severe secondary Psa symptoms in spring 2012, associated with heavy frosts in the affected blocks.
- In October 2012, lesions/cankers were either left untreated, cauterised using a blowtorch, or pruned 40 cm below the lowest observed symptom. Pruning cuts were sealed with Greenseal™ Ultra.
- Eighty-seven 'Hayward' and 72 Gold3 vines were included in the study, with lesions on 1 to 30 canes being monitored on each vine. In total there are of over 820 canes being monitored across the trial.
- Monitored lesions were on a range of wood ages, from last season's shoots to leader wood probably 4-10 years old.
- All lesions/cankers were marked at the start of the trial and lesion advance was measured at each assessment (to date, after 1, 3 and 7 months).
- In the cauterising treatment, if the lesion had advanced at any assessment time, the visibly active part of the lesion was re-cauterised.
- If any lesion was observed on pruned canes, another pruning cut was made 40 cm further in.
- The '40-cm' rule was relaxed on occasion where this would have substantially and detrimentally affected the structure of the vine, such as when it would have required cutting off a major portion of a leader.

3 Key Results

3.1 Progression:

'Hayward' Orchards

- A summary of leaf spot and shoot dieback symptom development up to May 2013 is presented in Figure 1.
- Incidence of leaf spotting was generally similar to that observed on the same orchards in the previous season, but with a slightly different progression pattern during the season.
- In the 2012/13 season, on two of the three orchards leaf spot incidence peaked in early summer, then declined from December onwards, a consequence of very few new infections and the growth of the canopy increasing the number of healthy leaves. In contrast, in the 2011/12 season, the incidence of leaf spotting continued to increase throughout the season on all orchards. The difference in the two years probably reflects the relatively wet summer in 2011/12 and very dry summer in 2012/13.
- In 2012/13, the number of shoots with secondary symptoms in Orchards #1 and #3 was similar to that observed in the 2011/12 season, but in Orchard #2 the numbers were substantially higher in the second year.
- Most of the secondary symptoms observed were in the current season's shoots. In most cases the lesions have not spread into older wood (Figure 3).
- The impact of secondary symptoms on the overall canopy structure is negligible in all three study orchards in the progression trial.
- New shoots were often observed emerging from healthy tissue near the base of healed lesions (Figure 3).

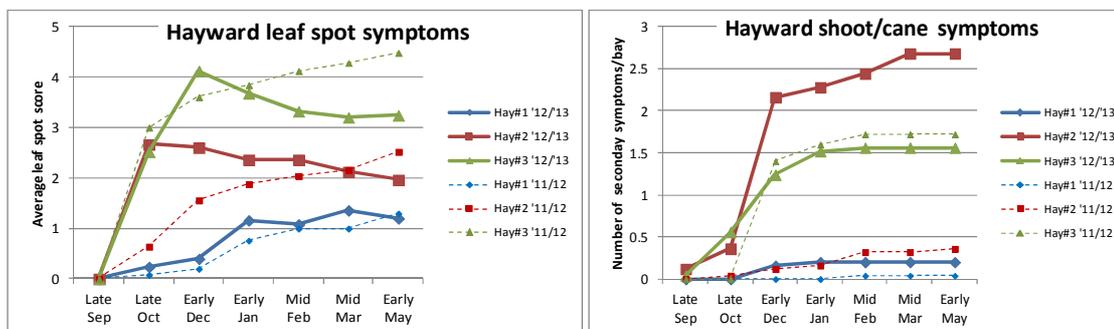


Figure 1. *Pseudomonas syringae* pv. *actinidiae* (Psa) disease severity recorded in bays during spring, summer and early autumn 2011/12 (dotted lines) and 2012/13 (solid lines), on three 'Hayward' kiwifruit orchards with the virulent strain, Psa-V. The same twenty-five bays per orchard were assessed regularly. For leaf symptoms (left), the percentage of leaves showing Psa-like symptoms in each bay was estimated and assigned to a disease severity class (0= none, 1= <1%, 2= 1-5%, 3= 5-15%, 4= 15-50% and 5 >50% of leaves with spot symptoms). Wilt/dieback symptoms (right) were recorded as the number of shoots in each bay with wilt, dieback or bacterial ooze symptoms.

Gold 3 Orchards

- A summary of leaf spot and shoot dieback symptom development up to May 2013 is presented in Figure 2.
- Leaf spotting was minor (on average, less than 1% incidence) on all three orchards.
- The number of canes per bay should be about 20-22 for each orchard. The average counts from 12 to 16 at the start of the season reflect pruning out of canes affected by Psa during winter/early spring 2012.
- On all three orchards, a number of monitored canes were pruned out because of Psa symptoms during the spring/summer season.
- The number of healthy canes remaining has continued to decline throughout the season. This is most obvious in Orchard #3, where, by May 2013, half the canes present in September were either diseased or removed because of Psa infection.
- Most lesions on canes have progressed rapidly, in many instances advancing from canes into leaders and trunks (Figure 4).
- Secondary symptoms were substantially more severe than those noted in the same vines in the previous season.
- The secondary symptoms, canopy death and subsequent pruning have had a substantial impact on the canopy structure in all three Gold3 study orchards.
- Some lesions have healed, with good callus formation (Figure 5). In some cases, canes have remained healthy beyond lesions that were marked as active early in the season, but subsequently healed. Callus usually appeared healthy, but sometimes was obviously diseased (Figure 5).
- New healthy shoots occasionally appeared at the base of infected canes (Figure 5).
- Lesions were frequently observed spreading from trunk or cane girdles (Figure 5).
- On one orchard, many new leaf spots appeared on leaves produced during a late summer growth flush.

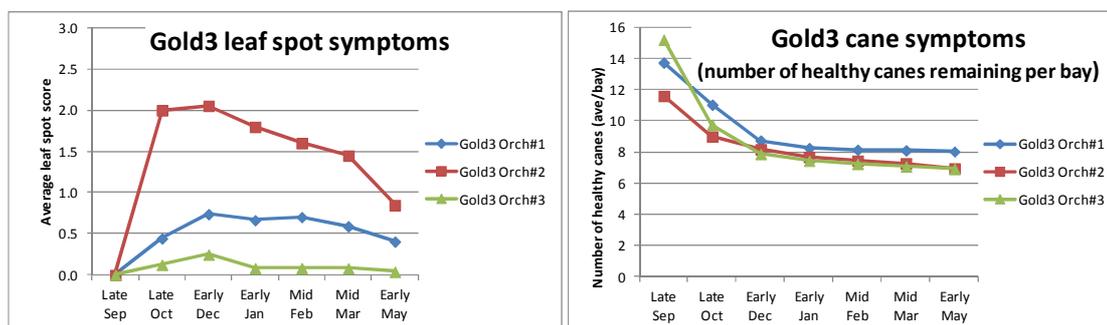


Figure 2. *Pseudomonas syringae* pv. *actinidiae* (Psa) disease severity recorded in bays during spring and early summer 2012/13, on three 'Zesy002' (Gold3) kiwifruit orchards with the virulent strain, Psa-V. The same twenty-five bays per orchard were assessed regularly. For leaf symptoms (left), the percentage of leaves showing Psa-like symptoms in each bay was estimated and assigned to a disease severity class (0= none, 1= <1%, 2= 1-5%, 3= 5-15%, 4= 15-50% and 5 >50% of leaves with spot symptoms). Wilt/dieback symptoms (right) were recorded as the average number of healthy canes per bay remaining at each assessment. On all three orchards, bays averaged 20 to 22 canes before Psa.



Figure 3. *Pseudomonas syringae* pv. *actinidiae* (Psa) shoot symptoms in 'Hayward' kiwifruit orchards with the virulent strain, Psa-V. Left and centre: Typical wilt of current season's shoots, with no obvious spread of symptoms into last year's cane. Right: new healthy shoot emerging at the base of infected shoot (broken off).



Figure 4. *Pseudomonas syringae* pv. *actinidiae* (Psa) shoot symptoms in Gold 3 (= 'Zesy002') kiwifruit orchards with the virulent strain, Psa-V. Top: lesions on current season's new shoots. Bottom: spread of cankers into main canes and leaders.



Figure 5. Cankers, callus formation and healing in Gold3 (=‘Zesy002’) kiwifruit vines infected with *Pseudomonas syringae* pv. *actinidiae* (Psa-V). Top left: Leader with extensive callus at base of canker, with apparently healthy tissue beyond. Top right: Canker showing partial callus, but with some diseased callus (right). Centre: Canker on cane showing signs of healing, with good fruit crop beyond. Bottom left: New shoot at base of infected cane/canker. Bottom right: canker spreading from girdle.

3.2 Intervention:

'Hayward' Orchards

- A summary of lesion progression data in the two 'Hayward' orchards collected in May 2013, 7 months after the trial was established, is presented in Figure 6.
- Pruning has, to date, proven effective in 'Hayward'. In Orchard #1, only 10 out of 72 pruned canes (13%) showed any signs of lesion advance in either the 3- or 7-month assessments. Seven of these ten canes were on the same vine. In 'Hayward' Orchard #2 even fewer lesions had advanced, with only three out of 130 (2%) pruned canes showing any sign of Psa advance after 7 months.
- Most pruning wounds had callused and apparently healed very well (Figures 8 & 9).
- All cases where lesions had advanced beyond the pruning cut were on canes that had not produced a complete ring of callus at the cut end (Figure 9).
- Callus formation on pruning cuts was better on Orchard #2 than on Orchard #1. This may be related to pruning done 2½ weeks later on Orchard #2 (early v. late October) when vine growth was more vigorous.
- In cauterised and untreated vines, the majority of lesions have continued to expand, with no obvious difference between these two treatments (Figure 6, Table 1).
- In Orchard #1, after 7 months 15% and 23% of lesions in the cauterised and untreated vines, respectively, have already expanded beyond the 40-cm mark (i.e. the distance the cut was made in the pruning treatment). In Orchard #2, 6% and 3% of lesions in the cauterised and untreated vines have expanded beyond the 40-cm mark. This expansion, together with expansion of many lesions currently less than 40 cm (Figure 6, Table 1), is likely to continue in the coming months.
- A small proportion of cauterised and untreated cane lesions formed callus around the margins and had apparently healed (Figures 8 & 10). In some cases this appeared to be healing in response to treatment with the blowtorch, but it also occurred in some untreated canes.

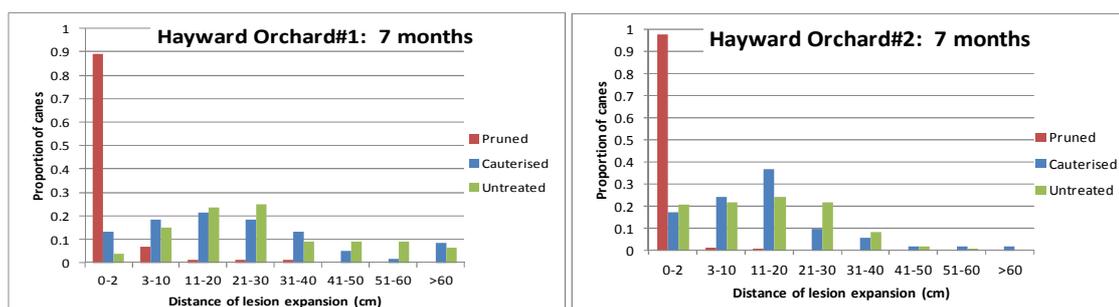


Figure 6. Lesion expansion on canes showing secondary symptoms of *Pseudomonas syringae* pv. *actinidiae* (Psa) in two 'Hayward' kiwifruit orchards, 7 months after all visible lesions were either pruned 40 cm below the lesion, cauterised using a blowtorch, or left untreated. For pruned vines, data are distances of lesion progression beyond the 40-cm pruning cut.

Gold3 Orchards

- A summary of lesion progression data in the Gold3 orchard collected in May 2013, 7 months after the trial was established, is presented in Figure 7.
- Lesion expansion in Gold3 was more aggressive than that noted in 'Hayward'.
- In some instances, after 7 months the monitored lesion was 'outflanked' by another lesion not visible or not noticed at the time the experiment was established. In such instances these data were excluded from the analysis.
- In the cauterised and untreated vines, more than 80% of lesions expanded beyond the original boundary marked in October.
- Pruning at 40 cm below the visible lesion did not prevent lesion expansion in 18.4% of cases. This compares with the 27.6 and 27.8% of lesions that have expanded beyond the 40-cm mark in the untreated and cauterised vines, respectively.
- All cases where lesions had advanced beyond the pruning cut were on canes that had not produced a complete ring of callus at the cut end (Figure 9).
- Many of the currently active lesions are likely to continue expanding in the coming months, increasing discrimination between treatments.
- Callus formation on pruning cuts was not as complete in Gold3 as that noted in 'Hayward', with only 30% of cane cuts forming 'good' callus (Figures 8 & 9). Cuts made during re-assessments in November and January had noticeably more complete callus formation than cuts made when the trial was established in early October.
- About 30% of cauterised cane lesions formed callus around the margins, and had at least partially healed. In some cases this appeared to be healing in response to treatment with the blowtorch, but it also occurred in some untreated canes, although to a lesser extent (Figures 8 and 11).

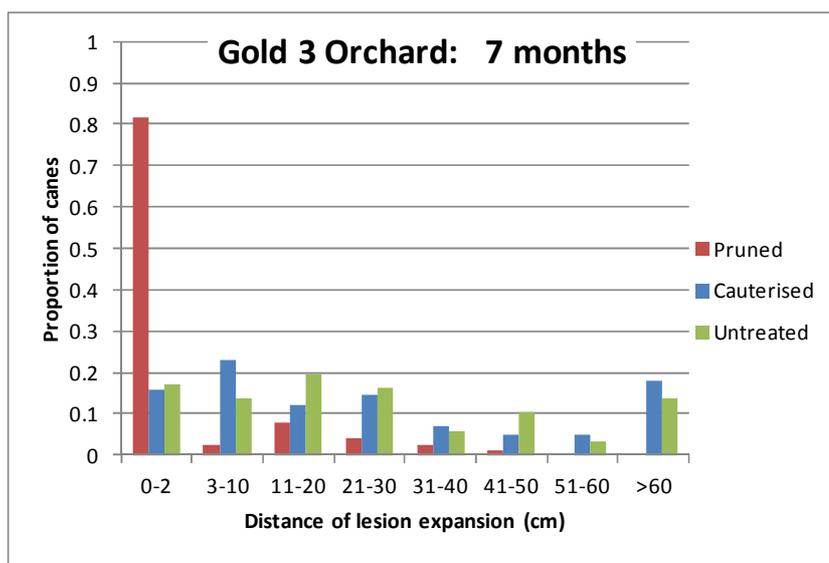


Figure 7. Lesion expansion on canes showing secondary symptoms of *Pseudomonas syringae* pv. *actinidiae* (Psa) in a 'Zesy002' (Gold3) kiwifruit orchard, 7 months after all visible lesions were either pruned 40 cm below the lesion, cauterised using a blowtorch, or left untreated. For pruned vines, data are distances of lesion progression beyond the 40-cm pruning cut.

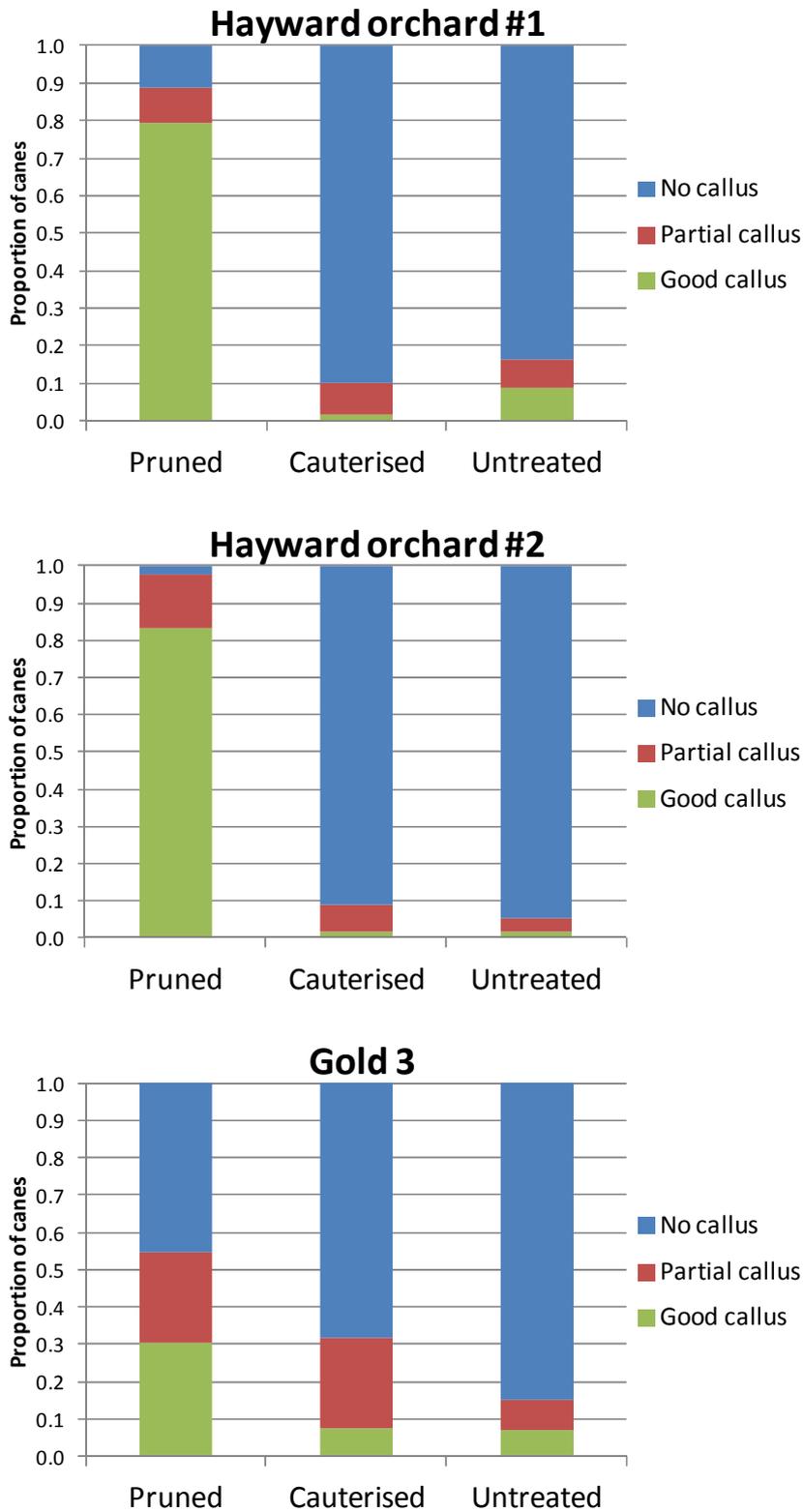


Figure 8. Callus formation adjacent to lesions or on pruning cuts recorded 7 months after treating kiwifruit canes with symptoms of *Pseudomonas syringae* pv. *actinidiae* (Psa) either by pruning 40 cm below the lesion, cauterising using a blowtorch, or leaving untreated. Data are from more than 820 canes on two Hayward and one 'Zesy002' (Gold3) kiwifruit orchard.



Figure 9. Plant responses after pruning kiwifruit canes 40 cm below cankers caused by *Pseudomonas syringae* pv. *actinidiae* (Psa). Healthy callus formation on 'Hayward' (top) and Gold3 (= 'Zesy002')(middle). Failure to produce callus and continued spread of Psa canker on 'Hayward' (bottom left) and Gold3 (bottom right).



Figure 10. Callus formation adjacent to cankers caused by *Pseudomonas syringae* pv. *actinidiae* (Psa) on 'Hayward' kiwifruit. Untreated leader (top left) and cane (top right). Callus formation beneath tissue cauterised using a blowtorch (bottom).



Figure 11. Callus formation adjacent to cankers caused by *Pseudomonas syringae* pv. *actinidiae* (Psa) Gold3 (=Zesy002') kiwifruit. Untreated (top left and right) and cauterised (bottom).

Table 1. Lesion expansion on canes showing secondary symptoms of *Pseudomonas syringae* pv. *actinidiae* (Psa) in two 'Hayward' and one Gold3 ('Zesy002') kiwifruit orchards, 7 months after all visible lesions were either pruned 40 cm below the lesion, cauterised using a blowtorch, or left untreated. Data are expressed as percentage of lesions that expanded from 10 to 40 cm or beyond 40 cm, measured from the leading edge of the initial lesion. The first 40 cm from the lesion was cut off in the pruned treatment, hence the '0' result in the 10-40 cm category in this treatment.

	Prune		Cauterise		Untreated	
	>40 cm	10-40 cm	>40 cm	10-40 cm	>40 cm	10-40 cm
'Hayward' #1	13.8	0	15.0	53.3	23.8	57.5
'Hayward' #2	2.3	0	5.8	52.4	2.7	54.5
Gold3	18.4	0	27.7	33.7	27.6	41.4

Pruning to 40 cm below the lesion is to date the most effective treatment at reducing spread of symptoms of Psa, in both 'Hayward' and Gold3. The number of lesions continuing to expand in the pruned canes is slightly lower in the pruned canes than the number of lesions beyond 40 cm in cauterised or untreated canes (Table 1). But the greater difference is likely to be in the lesions that are currently less than 40 cm in the cauterised and untreated vines, as many of these are still active and expanding. The assessment planned in spring 2013 should provide more definitive information.

Callus formation appears to be a good indicator of health. Where good callus formed on pruning cuts, Psa symptoms were halted. Where callus failed to form, Psa lesion spread continued. It is likely that the failure to form callus on pruning cuts reflects the presence of Psa at the site of the cut, thus preventing healing. This is consistent with observations in girdling experiments, where Psa-inoculated girdles failed to produce callus Snelgar (*pers. comm.*). With regard to pruning to remove Psa lesions, if callus formation is not obvious within a reasonable time frame, it is reasonable to assume incomplete excision of Psa (or new infection) and it is recommended that a further cut is made into healthy wood.

Pruning timing may affect healing and callus formation; it was noticeable that cuts made in late spring and into summer healed better than those made in early spring. Inoculum availability, prevailing weather, temperature, vine physiology and other factors could all be important, and are worthy of further investigation.

There is, to date, little evidence that cauterising lesions reduces lesion advance in Psa-infected wood. There may be slightly better callus formation in response to cauterising, and anecdotally the cauterising potentially dries up oozing cankers, but whether this has a long-term impact on vine disease is yet to be determined. The assessment planned for spring 2013 should help to determine any long-term benefits of cauterising lesions.

4 Future Research Steps

- All orchards in the Progression trial will have a final assessment of leaf and shoot dieback symptoms in spring 2013.
- A final assessment of lesion expansion in the intervention trial will be made in September/October 2013.
- A decision on the value of continuing assessments of these orchards for another season should be made in late winter/early spring 2013.



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