Towards development of a comprehensive spray programme for management of Psa-V in kiwifruit orchards - V11355

Zespri Innovation Project final report March 2014

Shirley Miller, Fiona Dean, Allister Holmes

PlusGroup, 37A Newnham Road, R.D. 4, Tauranga 3174

Executive Summary

This final report is a summary of key activities and outcomes over the past 15 months on a project designed towards testing on a commercial scale, a comprehensive spray programme, developed from results of previous trials, to minimise the impacts of Psa-V on orchard productivity.

The overall aim of the project was to take findings from previous research trials and integrate this information into a comprehensive orchard-scale spray programme that was tested on five kiwifruit orchards in the Western Bay of Plenty.

There were three main objectives:

- Quantify effects of the spray programme on spread and development of Psa in Hayward and G3 orchards
- Determine effects of the spray programme on canopy development, yield and fruit quality
- Measure impact of the programme on bud-break and plant health in the following season

The trial was conducted on three Hayward orchards and two G3 orchards in the Western Bay of Plenty region, with three replicate blocks at each orchard. The decision to spray was based on vine phenology and the KVH Psa-V Risk Model, an on-line decision support tool to help New Zealand kiwifruit orchardists manage orchard operations with respect to control of Psa. Psa symptom expression was conducted fortnightly in Spring and early summer when infection pressure was high, and monthly over the remainder of the year. Yield data was collected during the 2013 harvest and effects on bud-break were assessed in spring 2013.

Key Findings:

All growers had a rigorous Psa management strategy in place before the start of this trial and had maintained productivity and financial viability of their orchards over the past two years, i.e. since the discovery of Psa in 2010.

Low levels of disease occurred in both Test and Grower treated blocks, most likely because of the prolonged dry conditions over the first growing season, but in addition also suggesting that the spray programmes were similarly effective.

Neither the test spray programme nor any of the grower programmes prevented spread of infection. The test spray programme may have been more effective under higher disease pressure.

Frequent applications of copper in spring resulted in elevated foliar concentrations of copper with corresponding reduction in other divalent micro-nutrients such as manganese, and iron.

The test spray programme had an adverse effect on one of the G3 orchards causing phytotoxicity that resulted in a reduction of plant health, loss of leaves, and reduced yield.

Vine monitoring, with cankers removed and treated as they occurred, was a fundamental and crucial part of the Psa management process in this project.

Results suggested a well-timed Copper/Actigard spray after harvest may help with canker management, and thereby reduce sources of inoculum which lead to symptom development in the following growing season.

All growers except one used Key-Strepto® (streptomycin) at the beginning of Season 1, either before the trial started or shortly thereafter. Application of KeyStrepto® at leaf emergence (pre-flowering) may be of benefit in reducing symptom expression throughout the growing season, as was indicated at one of the G3 sites.

Spraying for Psa management had no adverse effects on bud-break or return bloom in the following season. The test and grower spray programmes were equally safe in this respect.

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Trial Description

The trial began in September 2012. Orchard selection included two Gold 3 and three Hayward orchards with varying degrees of expression of Psa symptoms at the start of the trial. Thus, there were five orchards in total, all in the Western Bay of Plenty. Symptom severity ranged from low to moderate, based on overall visual assessment of the orchard. The trial involved testing effectiveness of a standardised experimental spray programme (hereon referred to as test) in comparison with various 'grower's own' programmes in managing spread of Psa, allowing assessment of different product combinations. Details of the test programme were not fully disclosed to the growers with the aim of maintaining point of difference between the test programme and grower programmes. Spray treatments were established on blocks of approximately 0.5ha and there were three replicate blocks per orchard for each treatment, containing 580-1250 vines per replicate (Table 1). Details of vine density, male cultivars and proportion of male - female vines are shown in Table 2.

All growers had a Psa management strategy in place that involved a spray programme. Economic productivity of all orchards had been maintained since the outbreak of Psa-V in 2010. Each grower had a slightly different spray programme for Psa. The main differences between orchards were:

Orchard 1 (G3): Kocide® Opti™ (copper hydroxide) was applied on two occasions: at leaf emergence and just before harvest. Actigard™ was applied after harvest. Application of foliar and soil biologicals to encourage saprophytic micro-flora was a key focus in this orchard and so chemical intervention was minimal.

Orchard 2 (G3: Kocide® Opti™ (copper hydroxide) or Nordox® (copper oxide) was used occasionally during the growing season. KeyStrepto® was applied at leaf emergence and Actigard™ after harvest.

Orchards 3 and 4 (Hayward) used Nordox® as the main source of copper in Season 1, interchanged with the occasional application of Kocide® Opti™. Actigard™ was applied after harvest and copper sprays were maintained through dormancy. KeyStrepto® was used at leaf emergence in Season 1, and Kasumin® pre-flowering in Season 2.

Orchard 5 (Hayward) used Kocide® Opti™ as the only source of copper during the growing season. Actigard™ was applied after harvest and copper sprays (Kocide® Opti™) were maintained through dormancy. KeyStrepto® was applied pre-flowering in Season 1.

Sprays used in the test programme are shown in Table 3 with details of product used, frequency, rate and timing (stage in plant development). This information is summarised in comparison with each of the grower's programmes in Appendices (1-5)

The decision to spray experimental blocks was based on vine phenology in conjunction with the weather forecast and predictions of the KVH risk model. This model is an online, 'decision-support' tool available to kiwifruit growers to help identify environmental-risk periods and to assist with Psa-V orchard-management planning. It provides forecasts for high-risk and low-risk periods for Psa-V infection events on orchards. The 'risk forecasts' are based on weather parameters and daily probability of Psa-V infection events occurring on kiwifruit vines. KVH and Zespri developed the Psa-V risk model in collaboration with Plant & Food Research Ltd (P&FR) and the National Institute of Water and Atmospheric Research Ltd (NIWA).
Recommendations to spray were made when the risk model predicted a moderate - high risk of infection, usually coinciding with a heavy or persistent rain event, in which case the blocks were sprayed a few days beforehand to protect the vines from infection.

The trial spray programme started at shoot emergence and any sprays applied prior to the start of the spray trial were the grower's own choice.

The trial had three main objectives:

1. To compare a standardised, intensive Psa control spray programme with various spray programmes being used on commercial orchards, in order to quantify the effects on spread and development of Psa in Hayward and G3 orchards
2. Determine the effects of the spray programmes on canopy development, yield and fruit quality
3. Measure the impact of the programmes on bud-break and plant health next season

Table 1: Orchard selection, initial Psa status and management strategy

Orchard	Location	Cultivar	Situation	Initial Psa Status	Number of vines/rep/treatment					
					Trial treatment			Grower treatment		
1	Katikati	G3	Minimal chemical intervention by grower	Virtually symptomless	176	241	167	285	247	93
2	Katikati	G3	Grower using conventional sprays	Expressing (mild)	187	326	127	193	285	362
3	Te Puke	Hayward	Conventional sprays	Expressing (mild)	237	239	255	281	244	279
4	Te Puke	Hayward	Conventional sprays	Expressing (moderate)	231	224	221	272	193	206
5	Athenree	Hayward	Conventional sprays	Virtually symptomless	321	406	417	406	278	560

Block size was variable, based on orchard layout and ranged from 0.5 – 0.92ha. Planting density also differed between orchards, varying between 1-3 vines per bay.

Orchards 2, 3, and 4 were all confirmed as Psa positive before starting the trial, while Orchards 1 and 5 contained very minor symptoms and Psa had not been detected. All orchards were Psa positive by the end of the first growing season.

Table 2: Description of the five orchards used in the spray trial

Orchard	Cultivar	Vine density (vines/m^2)	Male cultivar	Proportion of Male - Female vines
1	G3	~30	Bruce M91	0.13
2	G3	~30	M33 M91	0.22
3	Hayward	28.6	Chieftain (~66%) M56 (~33%)	0.25
4	Hayward	23.7	Chieftain (~66%) M56 (~33%)	0.21
5	Hayward	~30	Chieftain (~60%) Matua, M series (~40%)	0.18

Table 3: Experimental (Test) spray programme: from September 2012 to November 2013.

Time	Product	Rate (100L)	Water (L/ha)	Rate (ha)	No. of apps	Frequency	Comments
Season 1							
Bud-break	Nordox® Du-Wett®	37.5g	600	225g	1 - 2	As required	Use Du-Wett® (40ml) as an adjuvant
Shoot emergence to canes extending	Kocide® Opti™ + Actigard™ Du-Wett®	70g 20g	600	420g 120g	3-4	15 day intervals (more if weather requires i.e. KVH risk model orange, red or purple)	Use 600L/ha at shoot emergence and small shoots. Rate was increased to 1000L/ha when canes were extending.
	KeyStrepto® + Actigard™	60g 20g	1000	600g 200g	2		KeyStrepto® was recommended but could not be applied because product is critically dependent on timing, i.e. no flowers allowed.
Pre-flowering	Nordox® Actigard™ Du-Wett®	37.5g 20g	1000	3755 200g	1	Immediately pre-female flowering before introduction of bees	Movento® for scale control and Prodigy (leaf roller) were used around the same time
Flowering	Spotless®	400ml	1000	4000 ml	1		All growers used Flint for Sclerotinia® control
Post-Flowering	Citrox-Bioalexin® Du-Wett stainless®	300ml	500 - 1000		3 - 4	15 day intervals or more frequent according to weather events	
Post flowering (40-60 days)	Nordox® Du-Wett®	37.5g	500-1000	750g	As required	40 days for Hayward 60 days for G3	Repeat after significant orchard events e.g. pruning, girdling and according to weather
Post-Harvest	Actigard™ Du-Wett®	20g	500-1000	400g	1		
Leaf fall & dormancy	Nordox® Du-Wett®	70g	1000	700g	2-5		Most growers used copper sulphate as a defoliant at 12.5kg per ha to speed up and condense natural leaf fall.

Table 3 (continued): Experimental (Test) spray programme: from September 2012 to November 2013.

Season 2							
Bud-break	Nordox® Latron B 1956	37.5g	600	225	1-2	At bud-break (green tissue) and then fortnightly	Latron at 20ml was used as an adjuvant without any apparent adverse effect
Shoot emergence through cane extension (~6 weeks)	Kocide® Opti™ Actigard™ Or Kasumin® + Kocide® Opti™	70g 20g	600	420 120	2	Start at shoot emergence, apply fortnightly in calm weather Target wet weather. Use lower rate in low infection pressure, high rate if high risk (bad weather coming or high disease)	Follow KVH predictive model, spray when yellow-orange
Pre-flowering	Nordox® + Actigard™ Duwett®	37.5g 20g	600		1	Single application as close to flowering as comfortable	

Objective 1: Quantify the effects of the spray programme

Psa monitoring

Monitoring for Psa symptoms began on 9th October 2012. Vines were assessed every two weeks up until 24th December 2012, after which monitoring was carried out monthly. Fortnightly monitoring was resumed in October 2013 and maintained until the end of the trial in November 2013. There were 17 rounds of monitoring in total. Vines were scored individually on each occasion for severity of leaf spots, cane dieback, cane cankers and leader cankers using a scoring system summarised in Table 4.

Table 4: Psa monitoring scores

Parameter	Score	Per vine
Leaf spots	0	None
	1	1-10 leaves with spots
	2	Up to 25% of the leaves have spots
	3	25-50% of the leaves have spots
	4	More than 50% of the leaves have spots
Leader cankers	0	None
	1	1
	2	2
	3	>2
Cane cankers	0	None
	1	1
	2	2
	3	>2
Cane dieback	0	None
	1	1-5 shoots with dieback
	2	>5 shoots with dieback

Leaf spot scores and cane dieback scores were accumulated over Season 1, and started again at the beginning of Season 2 after pruning. Accumulated scores were used to show potential disease build-up over the season. Once a score value had been assigned for a particular symptom, it could not be downgraded, for example after defoliation or cane removal. Leaf spot and cane-dieback scores for Season 1 and 2 were plotted over time using DeltaGraph™ and the data analysed using Statview 5.01™ statistical package (SAS Institute, Cary, NC, USA). Comparisons between spray programmes were performed using a 1-way ANOVA. The variety and gender data were analysed by nonparametric procedures.

Cane and leader cankers were scored individually as they occurred on vines and the data presented as total number of cankers experienced by each vine during the duration of the trial.

Objective 2: Determine the effects on canopy development, yield and fruit quality

Canopy measurements

Leaf Nutrients

Leaf samples were taken from test and grower treated trial blocks in each orchard on two occasions (November 2012 and January 2013) using BioSoil & Crop standard sampling methods. Thirty-two leaves were collected evenly across each block using a diagonal or zigzag pattern (Figure 1). Each leaf sampled was the largest mature leaf from a fruiting cane selected approximately one metre from trunk.

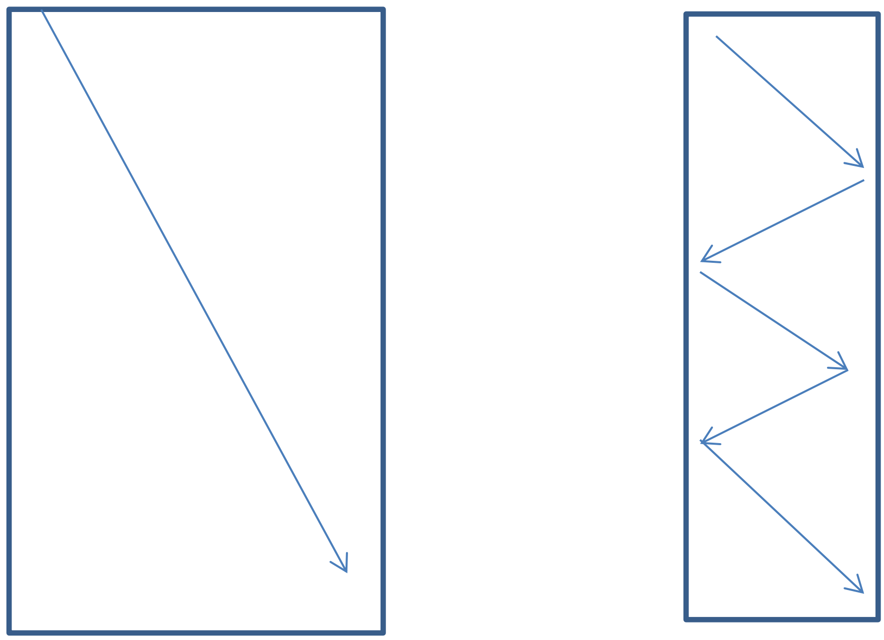


Figure 1: Collection of leaf samples for nutrient analyses across blocks

Every fourth leaf and last leaf was put aside and the remaining twenty five leaves were measured for length from joint with petiole to tip and width at widest point. Shape ratio was calculated from these length and width measurements.

Four points on seven leaves were measured using Opti-Science Chlorophyll Content Meter to compare chlorophyll activity.

Chlorophyll content was measured from 50mm disc taken from the centre of seven leaves. Wet weights of these discs were recorded before drying at 60°C in a food dehydrator and dry weights were then recorded.

Once physical measurements had been completed, un-washed leaves were oven dried at Hill Laboratories in Hamilton and analysed for foliar nutrients.

Harvest Measurements

Fruit Yield and Quality

Fruit harvest took place over a 4-week period, starting 19th April 2013 on the G3 orchards, followed by Hayward starting 9th May (Table 5). Wherever possible, test and grower blocks were harvested on the same date; the only exception being Orchard 2 where the test programme blocks were picked 12 days later than the grower blocks due to delayed maturity. All fruit picking was completed by 14th May.

Residue testing was carried out before harvest with samples collected by AgFirst personnel approximately two weeks prior to harvest. Analyses were carried out by Hill Laboratories (Hamilton). Samples from test and grower blocks on each orchard were analysed separately with fruit from each of the three replicates bulked and analysed as composite samples.

Table 5: Harvest dates for test and grower treatments on the five trial orchards

Orchard	Cultivar	Harvest Date	
		Test	**Grower**
1	G3	26/4/13	26/4/13
2	G3	7/5/13	19/4/13
3	Hayward	14/5/13	14/5/13
4	Hayward	9/5/13	9/5/13
5	Hayward	13/5/13	13/5/13

Prior to harvest, "clearance to pick" sampling was carried out by AgFirst personnel using their standard protocols. Parameters measured on 90 individual fruit samples from each of the three replicates were: weight (g), °Brix, dry matter (%), firmness (kgf) and colour (G3). Each of the blocks in the test and grower programmes were treated as separate maturity areas for clearance samples and the collection of pack-house data. Thus, there were 30 lots of fruit processed, comprising 5 orchards x 2 treatments x 3 replicates.

Pack-house data was used to determine treatment effects on yield, size and grading profiles for each orchard. Financial return for each orchard/treatment was estimated using the Zespri on-line OGR calculator and industry averages for expenditure. Spray programme costs were deducted separately for each individual orchard.

Objective 3: Measure the impact on bud-break and plant health next season

Methodology

Winter bud count

Contractors organised by respective growers or managers pruned vines on each of the five trial orchards. Average numbers of winter buds per m^2 were calculated for test and grower treatments from bud counts in early September after canes had been tied down. One bay was chosen at random in three separate rows across each of the three replicate blocks. Thus for each orchard there were 3 x 3 = 9 counts.

Orchard 5 was an exception as a replicate of each treatment was removed from the trial at the end of Season 1. Thus for Orchard 5, there were only two blocks counted.

All orchards were assessed visually during October and November in Season 2, looking in particular for signs of bud-rot in the two Hayward orchards in Te Puke (Orchards 3 and 4). Overall appearance of the vines in each orchard was discussed with the growers in order to gauge general vine health within each of the spray treatments.

Results and Discussion

Objective 1: Effects of the spray programme

Orchard assessments

Pre-spray Psa-status

All growers had a Psa management strategy in place before the trial started. This included applications of copper based fungicides throughout dormancy. One G3 grower had also used KeyStrepto® in the lead-up to the trial.

After the trial started KeyStrepto® was used in the grower spray programmes on the three Hayward orchards (pre-flowering), but not in the test programme.

All orchards showed symptoms of Psa disease at the start of the trial before the spray programme was started. Initial levels of infection in the trial orchards were classified from virtually symptomless to moderate based on calculated means of symptom scores in individual vines (Table 6).

Coincidentally, cane dieback was significantly higher at the start of the trial in grower blocks of orchards 1 and 2 (p = 0.0001) and similarly in orchard 5 (p = 0.005). The mean numbers of cane cankers were also higher in the grower blocks in orchard 3 at the start of the trial, and there were no leader cankers in either treatment of any orchard. Potentially, these initial differences between blocks may have biased the data and resulted in false conclusions about spray effectiveness between treatments. However, the pattern of symptom development over the season was similar for both test and grower blocks, indicating that initial levels of infection appear to have little influence on the rate of disease build-up over the season.

Table 6: Initial Psa symptom scores for Test and Grower blocks

		Test treatment				**Grower treatment**			
	Initial Psa status	Leaf spots	Cane dieback	Cane cankers	Leader cankers	Leaf spots	Cane dieback	Cane cankers	Leader cankers
1	Virtually symptomless	0	0	0	0	0	0.03***	0	0
2	Mild	0	0.018	0	0	0.002	0.129***	0	0
3	Mild	0	0.021	0.004	0	0	0.079	0.023**	0
4	Moderate	0	0.012	0.009	0	0.02	0.009	0.003	0
5	Virtually symptomless	0	0	0	0	0	0.019*	0	0

*** $p < 0.0001$, ** $p < 0.005$, * $p < 0.05$

Symptom expression was low in all orchards, and the means were calculated from three replicates of 200-400 vines per rep (i.e. 600-1200 vines), hence values recorded were very small

Weather summary and risk of infection

Early in Spring 2012 (September – November) the risks of infection were moderate in Te Puke, and slight to moderate at Apata which was the nearest weather station to the Athenree orchard. Risks were higher for both regions in December due to increased rain events.

There was very little rain through January – March 2013 and the likelihood of infection during these months was correspondingly low most of the time according to the KVH risk assessment model. The risks were upgraded to moderate to high in April when rainfall increased. Over the winter of 2013 there were more occasions in Te Puke than in Apata when the risks of infection were moderate to high. Spring 2013 in the Western Bay of Plenty was relatively dry and risks of infection at this time were mostly slight to moderate (Table 7).

Table 7: Number of occasions over the 2012-2013 season when the risk of infection by Psa was either: Slight, Moderate or High, based on the KVH risk assessment model

		Te Puke Research Centre			Apata		
		Slight	Moderate	High	Slight	Moderate	High
September	2012	0	9	0	11	2	0
October	2012	0	8	0	7	3	0
November	2012	0	5	0	4	2	0
December	2012	0	9	4	1	10	1
January	2013	0	0	0	2	0	0
February	2013	0	0	0	3	0	0
March	2013	0	3	0	5	2	0
April	2013	0	2	4	0	4	4
May	2013	0	4	9	3	8	3
June	2013	0	6	6	2	8	3
July	2013	0	6	0	4	3	0
August	2013	0	9	3	8	8	0
September	2013	0	7	4	5	5	2
October	2013	0	7	0	7	0	0
November	2013	0	5	4	2	5	0
December	2013	0	5	3	5	4	0

Psa Monitoring

From the date that the trial was initiated in September 2012 until November 2013, 17 monitoring rounds were completed. Psa scores for each symptom type (leaf spots, cane-dieback and cankers) were recorded on each occasion for each vine.

By monitoring each vine individually from October 2012 to November 2013, it has been possible to build up a picture of symptom development over the beginning of two seasons for each orchard, and compare effectiveness of a test spray programme with the grower's own practices. Presence and spread of symptoms were plotted using DeltaGraph® for each of the orchards.

Note; assigning equal weightings to symptoms may not be a fair approach for assessment of disease severity – for example development of symptoms such as leader cankers could be considered more serious than leaf spots from which the plant may be able to recover. Amalgamating symptoms and assigning weightings to give an overall severity rating could be considered for further statistical analyses if required.

Symptom expression was generally low level in both test and grower treated blocks, particularly in orchards with mild infection levels at the start of the trial. Highest scores were recorded in Te Puke on the Hayward orchard with moderate initial symptoms. Low symptom expression throughout the period of the trial was most likely because of the prolonged dry conditions over the first growing season.

Treatment effects

Leaf spots

Average leaf spot scores were low for all orchards over the 2012-2013 growing season (Figures 2a & 2b: A-E). The average score was about 0.2 out of a possible maximum of five for the G3 orchards and 1.0 on the same scale for the Hayward orchards. Whereas the Hayward orchard in Athenree (orchard 5) remained virtually symptom-free over the first growing season, leaf spotting was recorded in early Spring of Season 2 indicating the inevitable wider spread of Psa over the 2013-2014 season within the Bay of Plenty. Leaf spotting was the most common symptom recorded on Hayward vines in the Te Puke region (orchards 3 and 4), occurring on both male and female vines. Spots with characteristic halos were first recorded in late October 2012 and showed steady progress over the season with an average leaf score of one by mid-January (up to 25% of the canopy affected).

Leaf spotting in Hayward first occurred about one month earlier in the following season (Season 2), and appeared to be progressing at approximately the same rate when the trial was terminated in November 2013. There was significantly ($p < 0.05$) less leaf spotting recorded in grower treatments than test treatments in the Hayward orchards (Figure 2b: orchards 3, 4 and 5).

In contrast with Hayward, leaf spotting on G3 vines was less severe, and did not occur until mid-January 2013. Leaf spots are generally recognised as a rare occurrence on G3 and in this trial were always at a lower level compared to the Hayward orchards. Leaf spots in G3 were typically observed in rows adjacent to shelterbelts.

Orchard 1 (G3) had significantly less spotting in the grower treated blocks ($p < 0.05$), while there were no significant treatment differences in the second G3 orchard (Figure 2a).

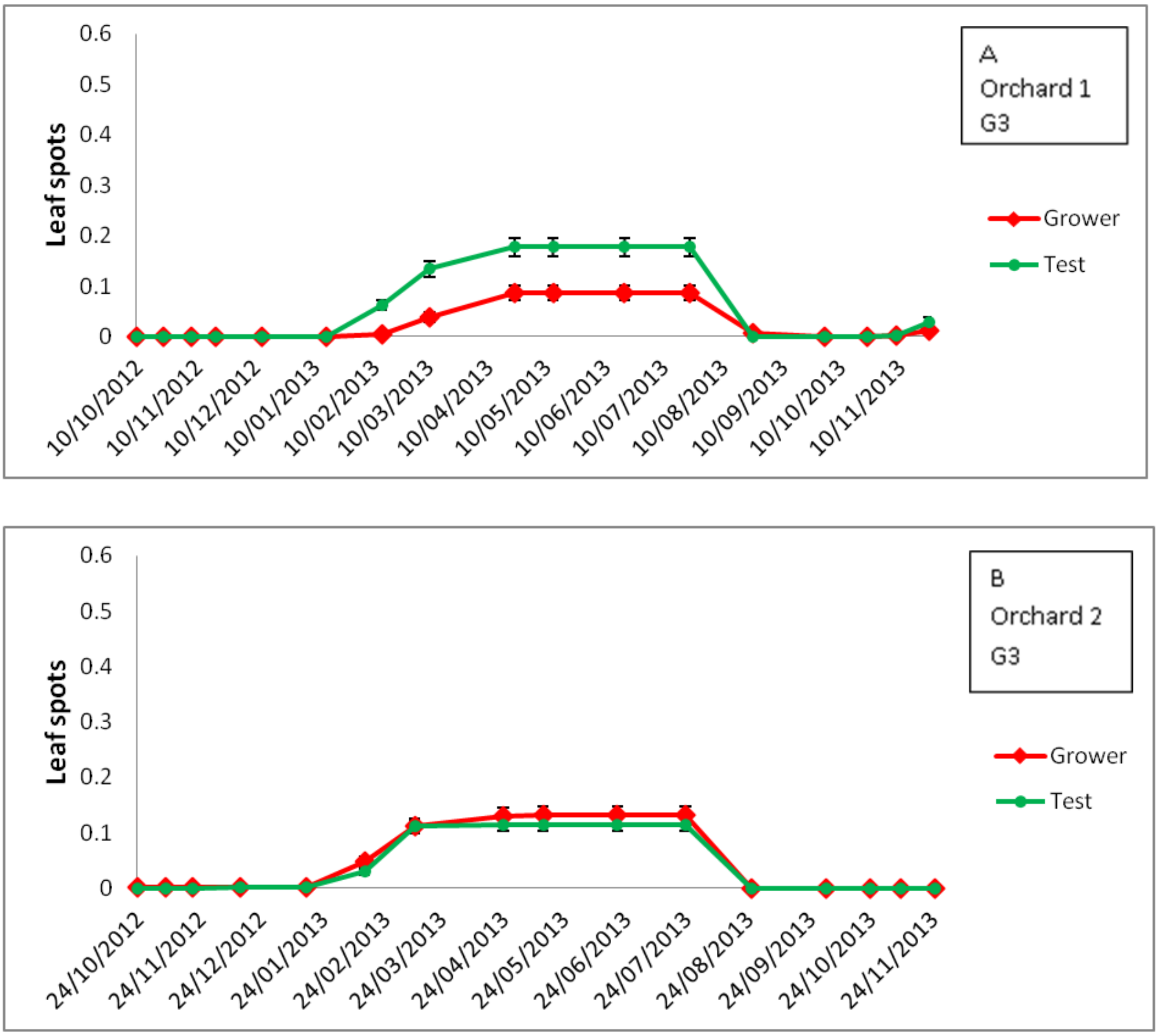


Figure 2a: Leaf spot symptoms recorded for G3 (orchards 1 & 2)

Comparison of Grower ● and Test ● spray programmes.

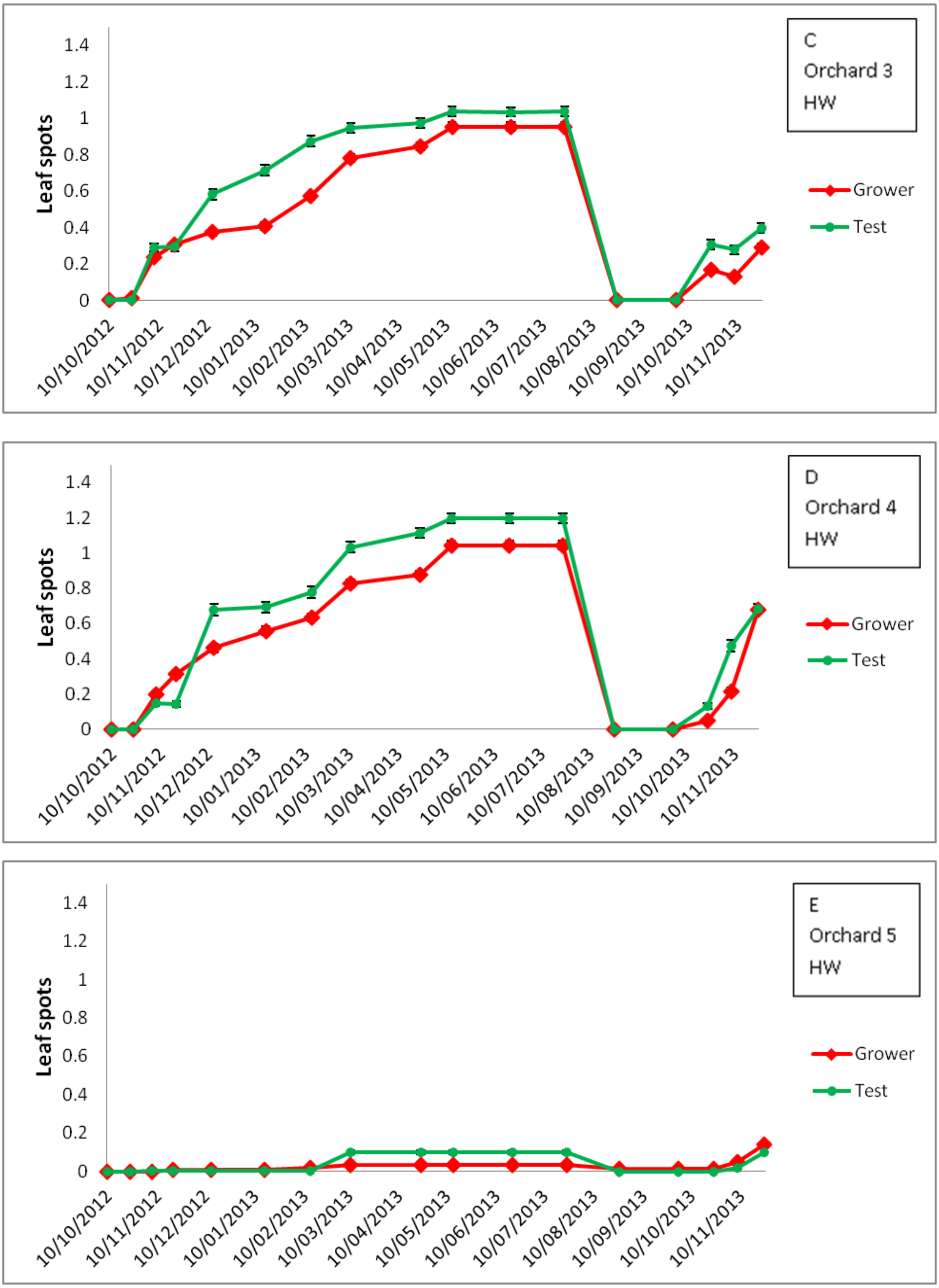


Figure 2b: Leaf spot symptoms recorded for Hayward (orchards 3, 4 & 5)

Comparison of Grower ● and Test ● spray programmes

Cane dieback

Cane dieback occurred in all orchards. There was a general trend for test blocks to have lower dieback scores than grower blocks. Cane dieback was significantly less (p<0.05) on test blocks of the Hayward orchards, and similarly on orchard one of the G3 orchards, at least until mid-April after which there were no differences between treatments. (Figures 3a & 3b).

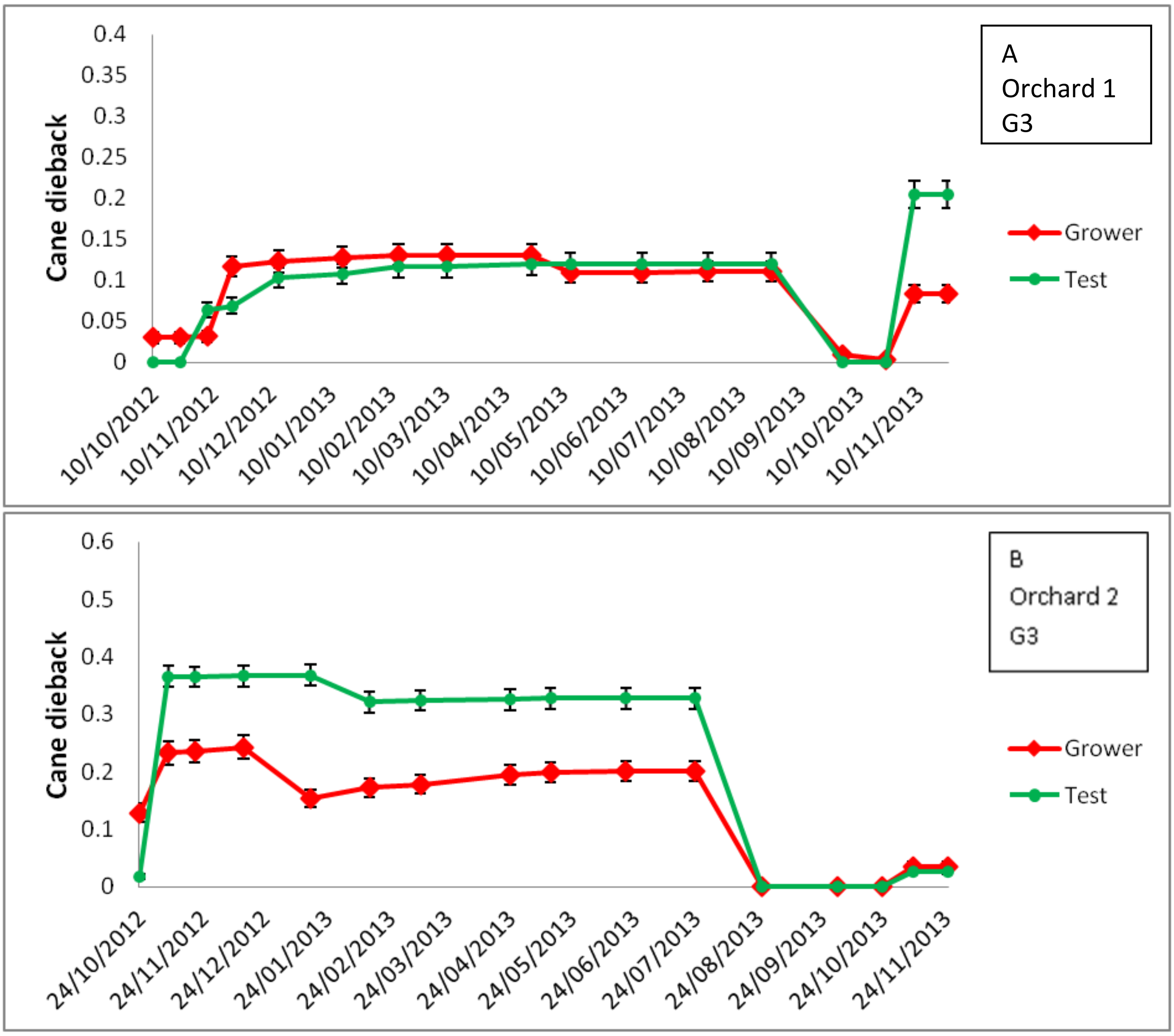


Figure 3a: Cane dieback scores recorded for G3 (orchards 1 & 2)

Comparison of Grower ● and Test ● spray programmes

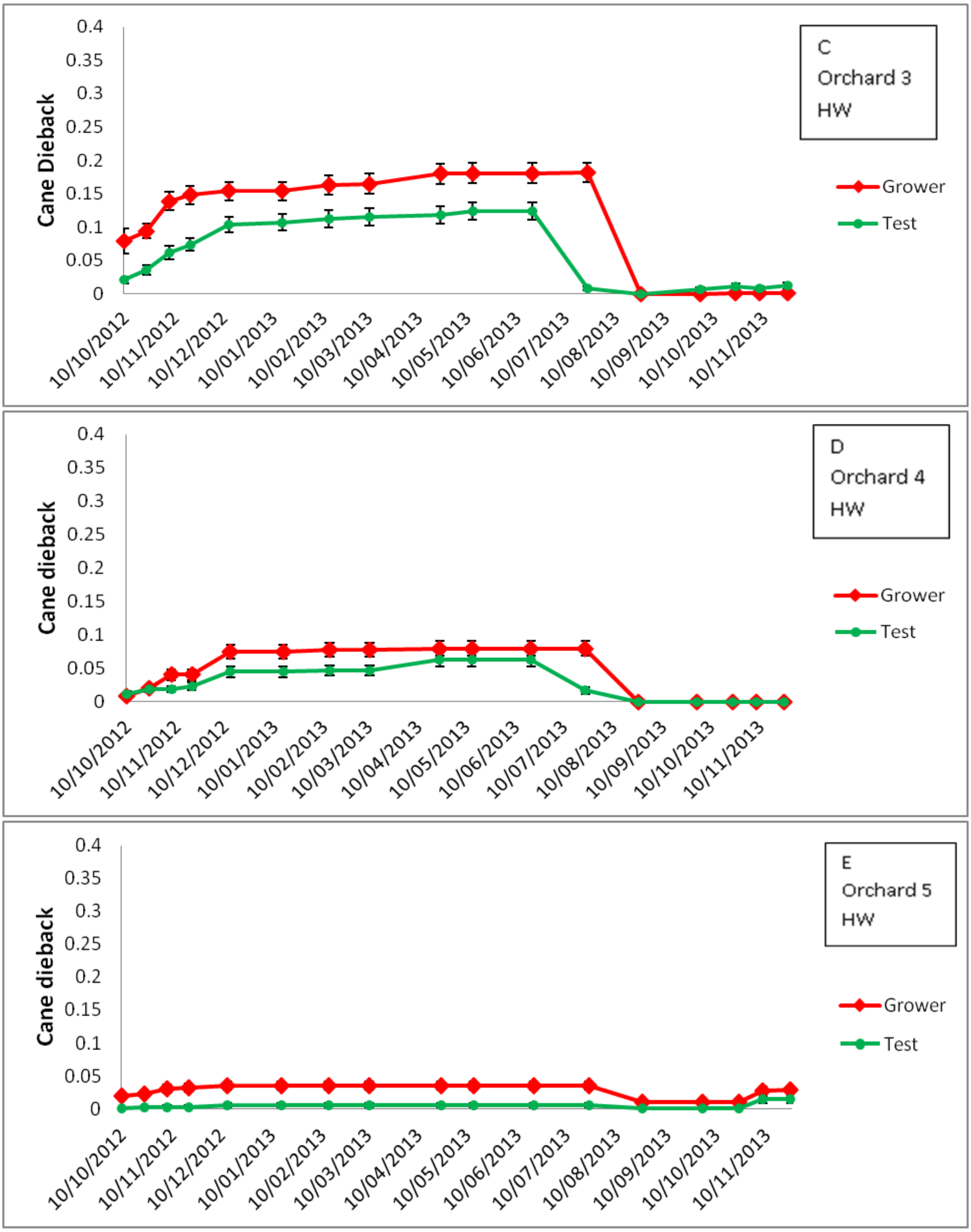
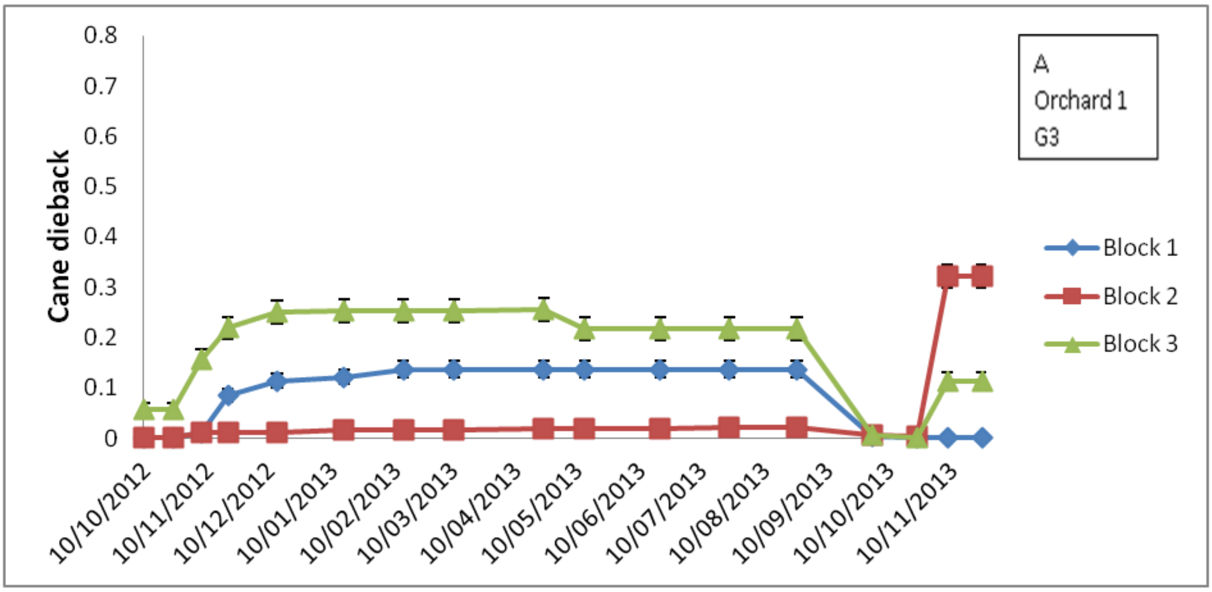


Figure 3b (C-E): Cane dieback scores recorded for Hayward (orchards 3, 4 & 5)

Comparison of Grower ● and Test ● spray programmes

Cane dieback was the dominant symptom recorded in G3 orchards for most of Season 1 with male vines particularly affected early in the Spring. It is assumed that these canes were infected by Psa but samples were not taken for diagnosis and identity of the pathogen was not confirmed in laboratory tests. Low temperature damage is another cause of shoot dieback, and may pre-dispose vines to infection. Highest dieback scores were recorded in this trial in lower elevation blocks prone to cooler temperatures and higher humidity. For example, block 3 in Orchards 1 and 2 was lower than the other blocks and adjacent to a dam and these blocks had more symptoms (Figure 4a). This is consistent with observations from other commercial orchards. The significant (p<0.05) differences between all blocks in Orchard 1 is less easily explained. Vines in blocks 1 and 2 were of the same age and the sites were geographically similar. This could warrant further investigation. There were no block differences recorded on the Hayward orchards in this trial (Figure 4b).



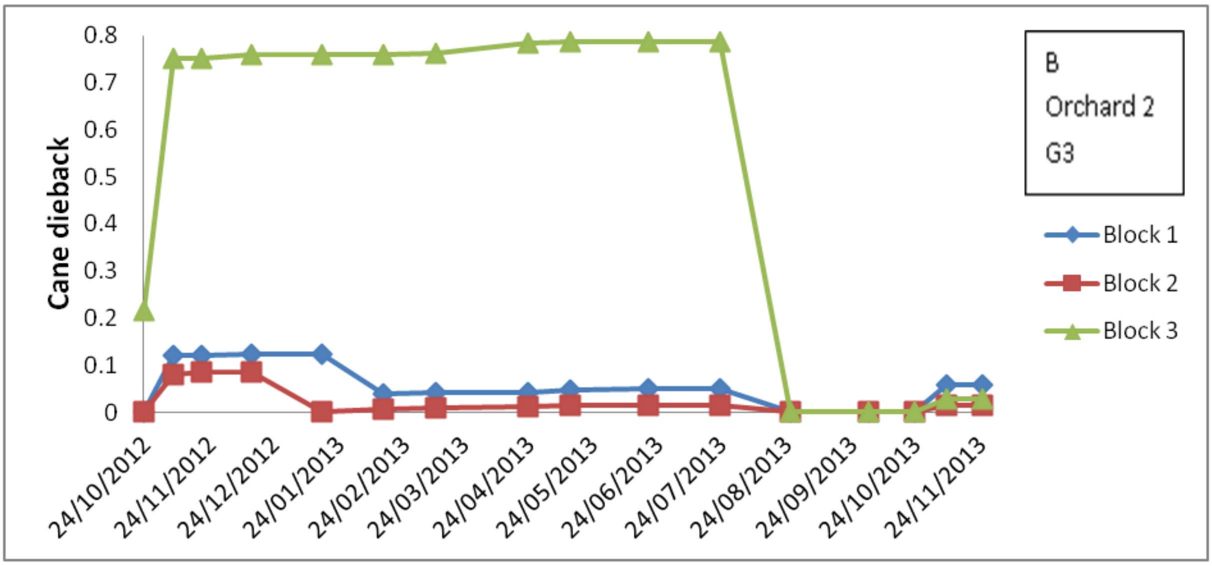
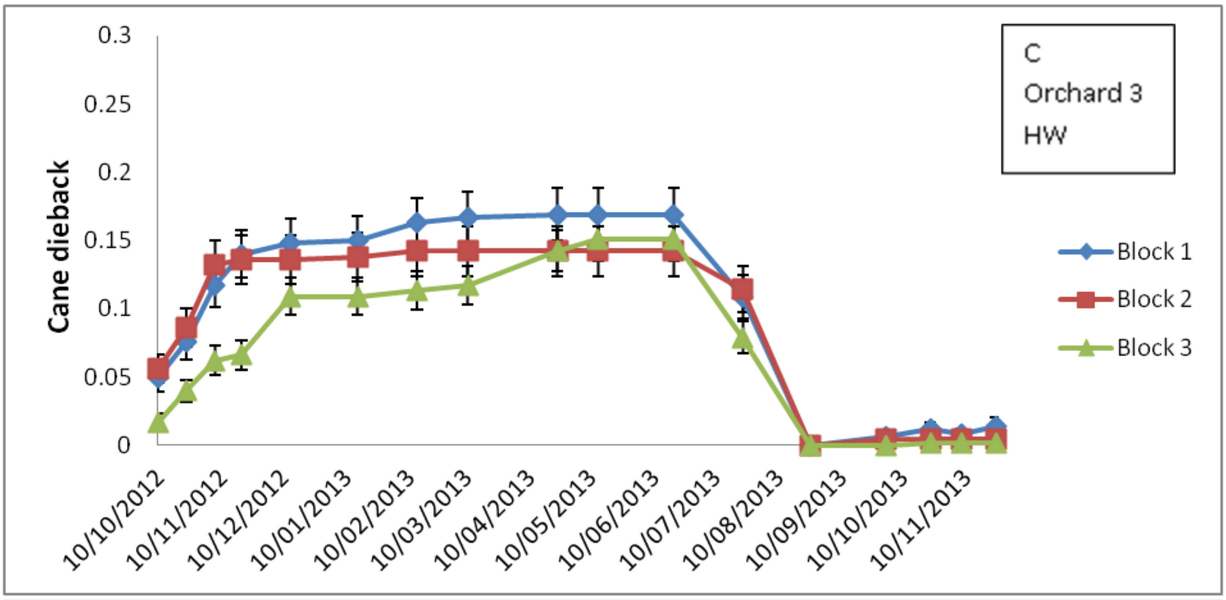
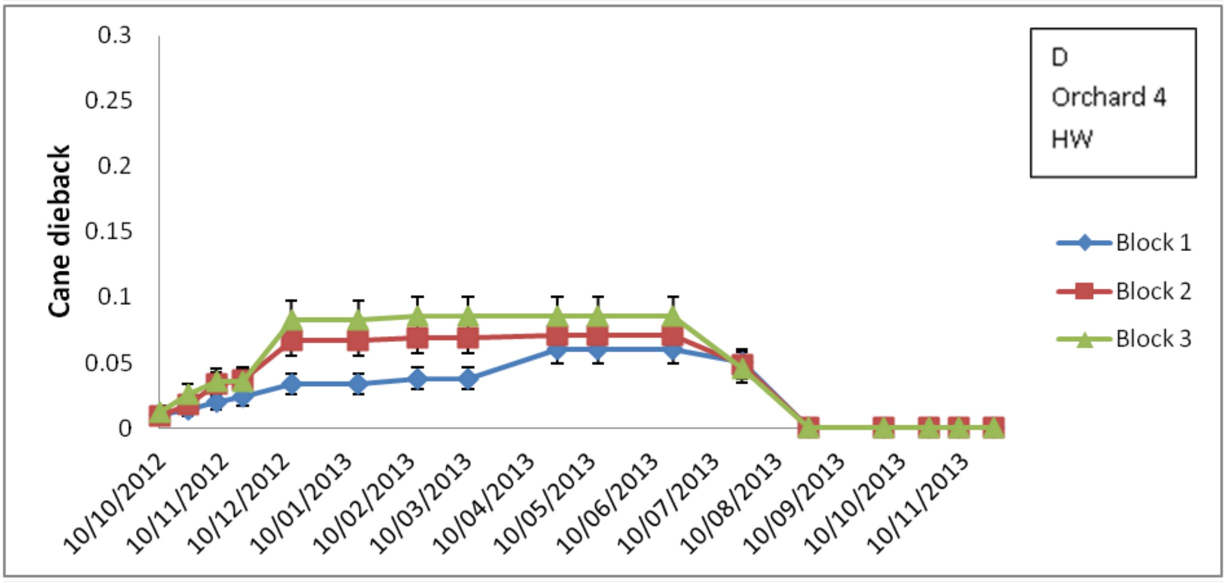


Figure 4a (A-B): Overall effect of orchard block on spread of cane die-back (combined spray programmes) G3 orchards 1 & 2





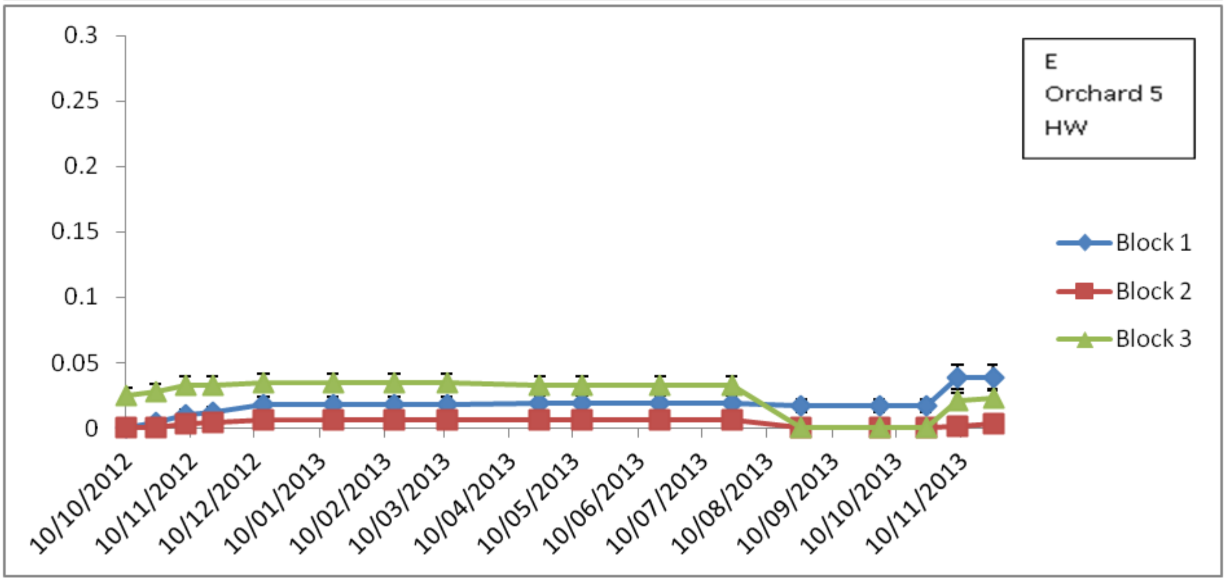


Figure 4b (C-E): Overall effect of orchard block on spread of cane die-back (combined spray programmes) Hayward orchards 3, 4 & 5

Male & Female vines

Male vines in G3 orchards were particularly affected by cane dieback early in the Spring. Overall, for both varieties, male vines mostly had the highest scores for leaf spots and cane dieback (Figures 5 & 6). The exceptions were Orchard 1 (G3) where female vines had higher cane dieback scores and Orchard 4 (Hayward) where female vines had higher leaf spot scores than male vines. Differences were significant (*p*< 0.05). The data suggest there may be differences in tolerance to Psa between male cultivars. Also, the arrangement of male vines in orchards differed between orchards, as did the ratio of male to female vines and overall male vine management strategy. All of these factors are likely to play a role in determining severity of symptom expression.

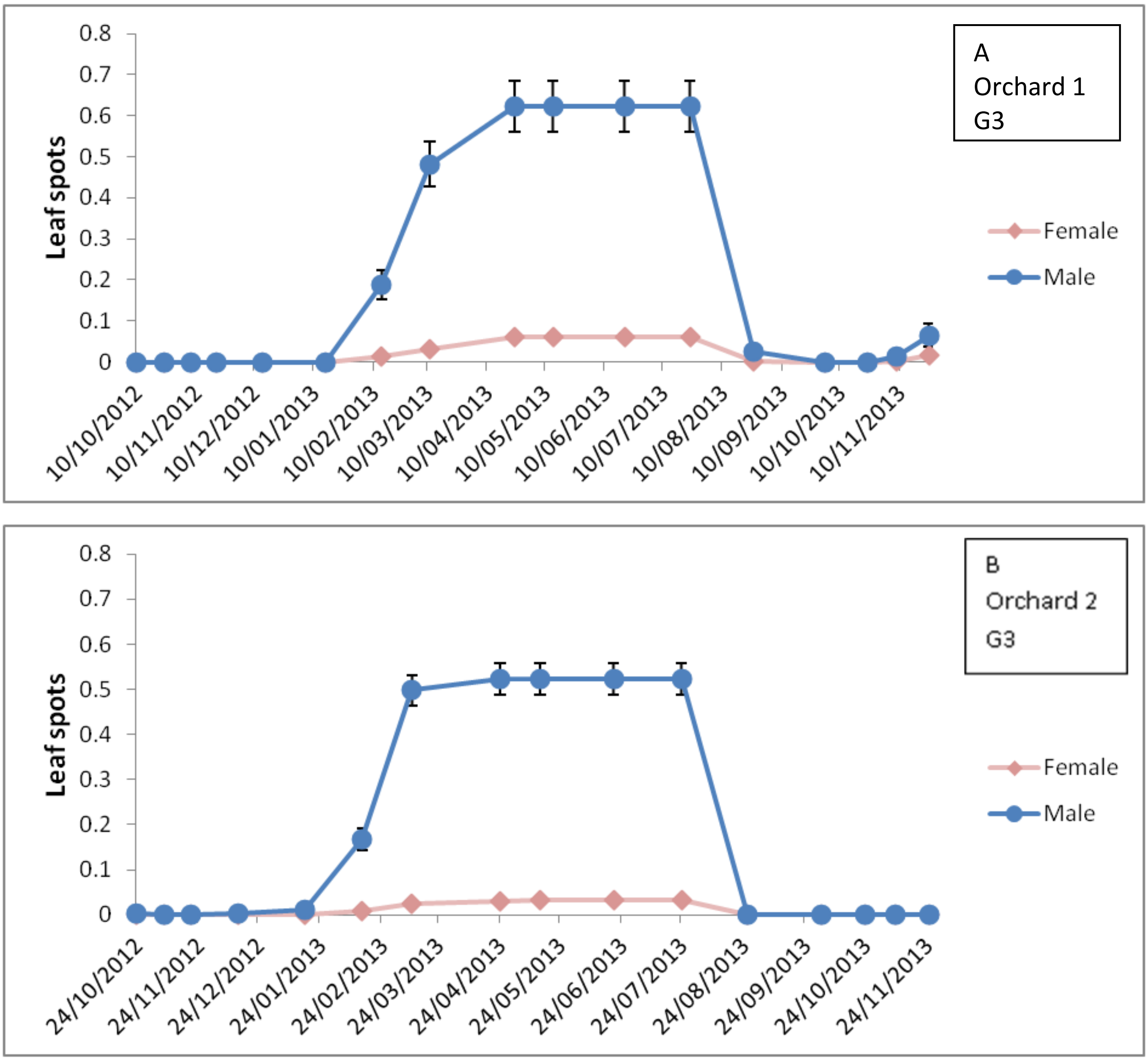


Figure 5a (A-B): Leaf spot symptoms recorded for female and male vines (combined spray programmes) G3 orchards 1 & 2

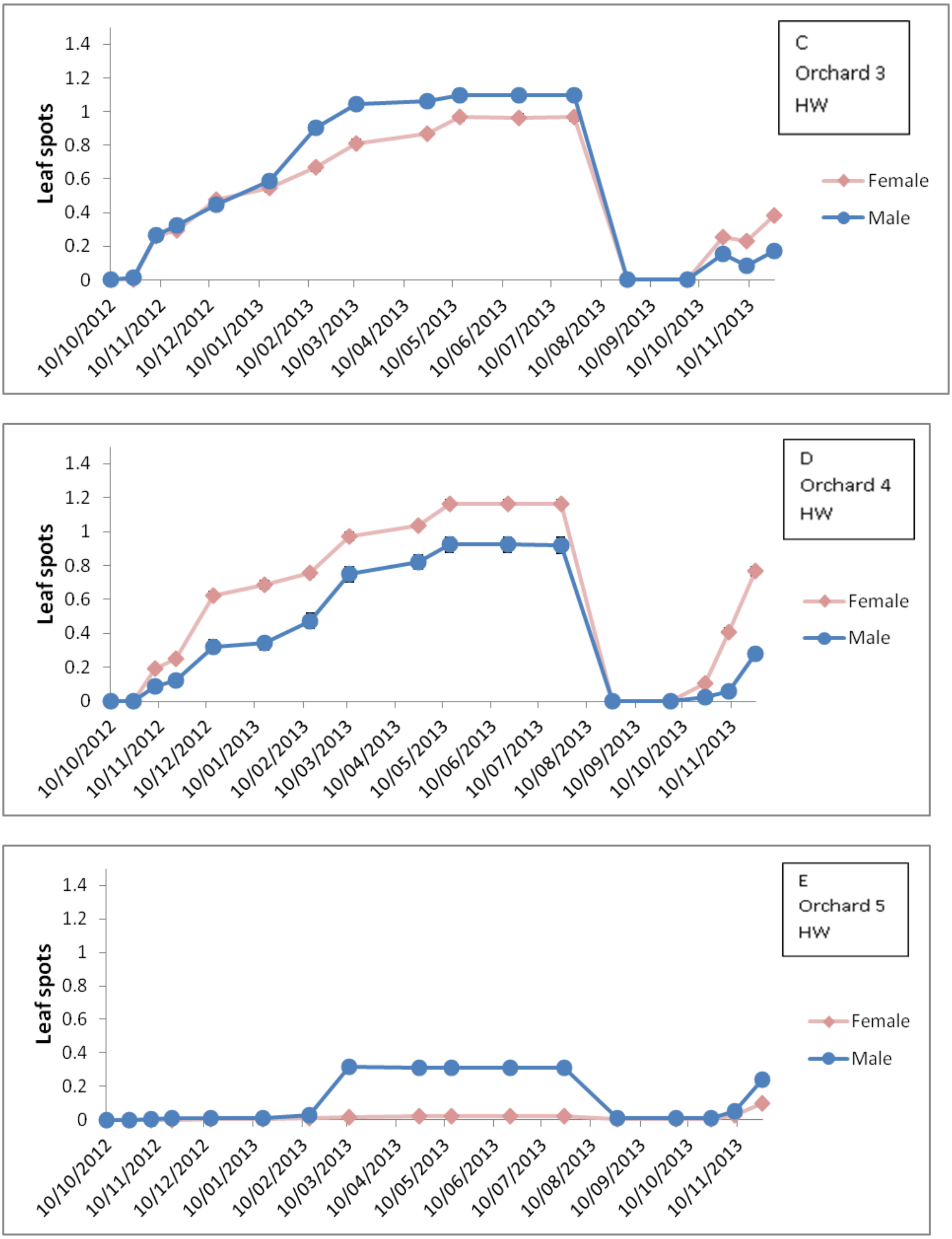
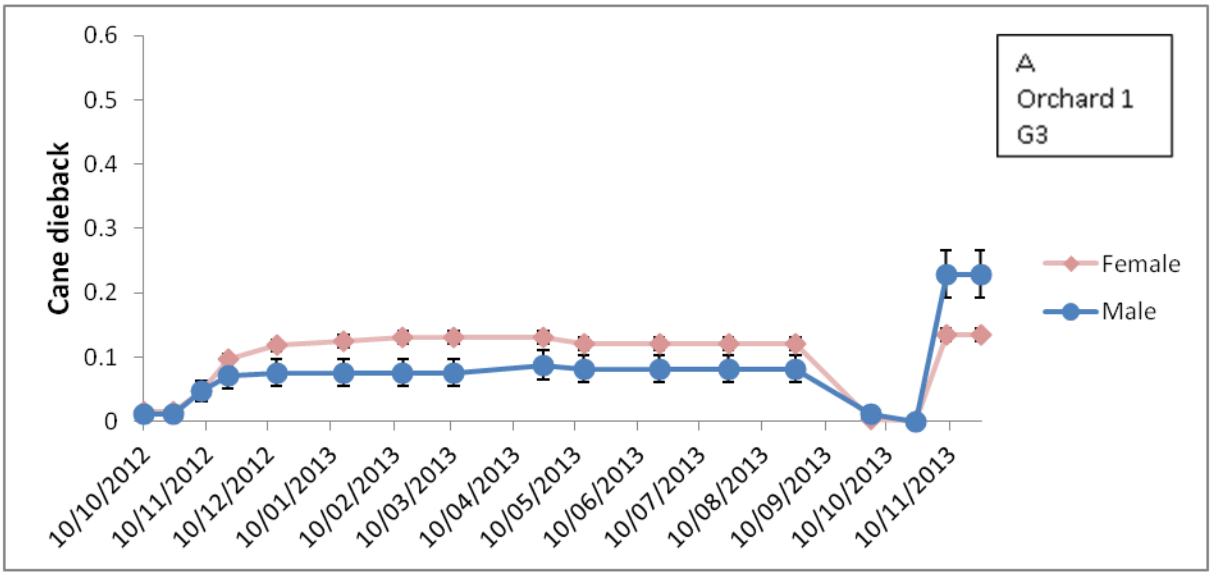


Figure 5b (C-E): Leaf spot symptoms recorded for female and male vines (combined spray programmes) Hayward orchards 3, 4 & 5



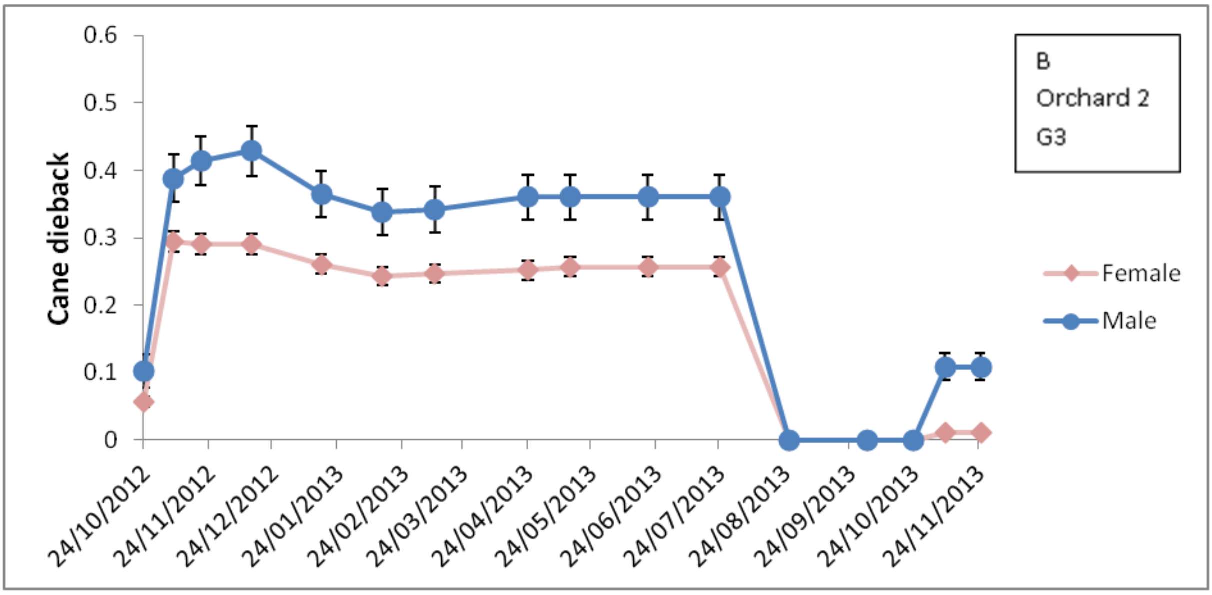
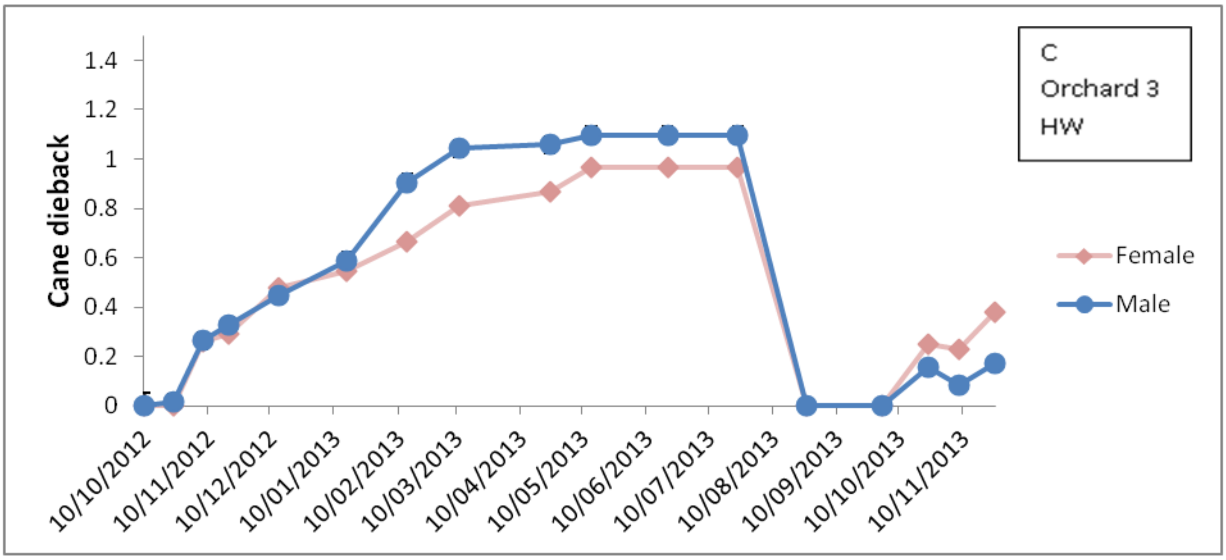
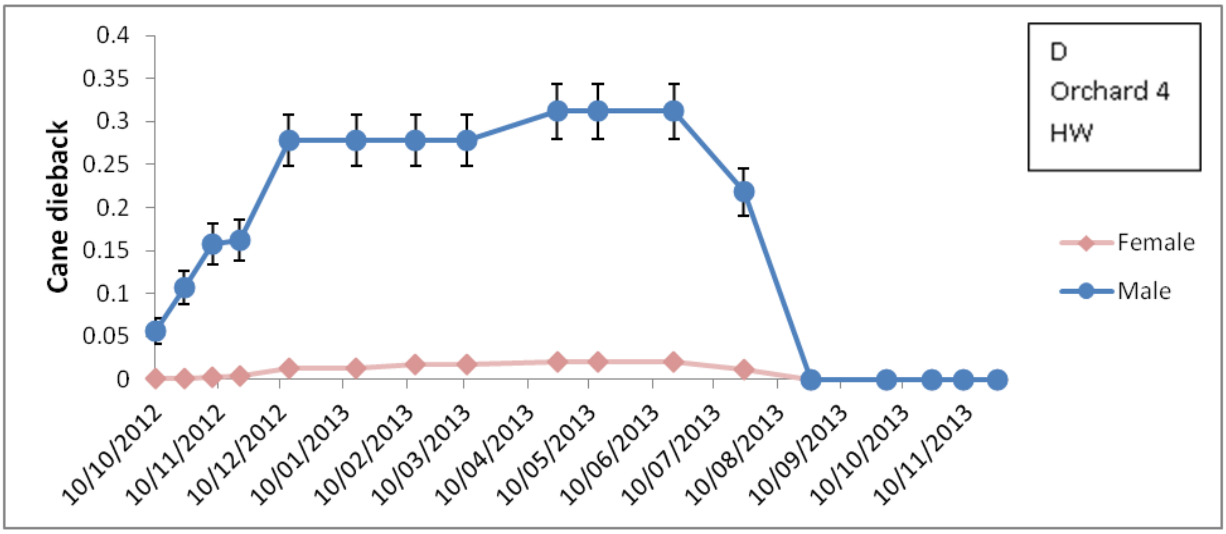


Figure 6a (A-B): Cane dieback symptoms recorded for female and male vines (combined spray programmes) G3 orchards 1 & 2





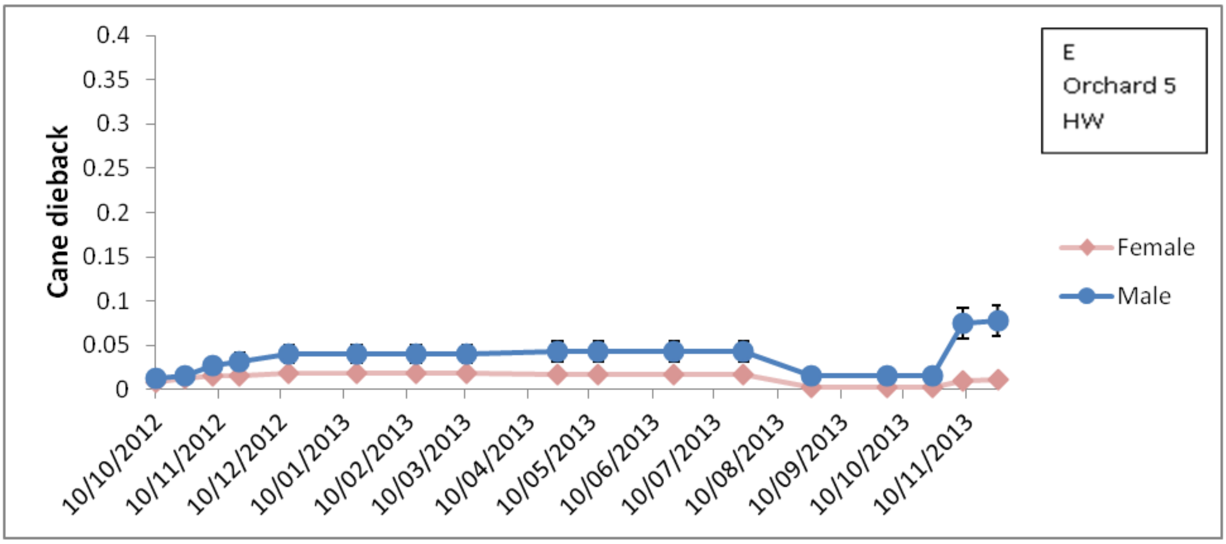


Figure 6b (C-E): Cane dieback symptoms recorded for female and male vines (combined spray programmes) Hayward orchards 3, 4 & 5.

Cankers

Overall incidence of leader and cane cankers was low throughout this trial, irrespective of spray programme (Table 8). After an initial outbreak in Spring 2012, numbers of cankers remained low throughout the summer most likely due to dry conditions over the 2012-2013 growing season. Leader and cane cankers occurred on both male and female vines. There were fewer cankers at the start of Season 2, possibly due to prolonged low-risk conditions over winter combined with regular use of copper sprays throughout dormancy. In addition, all orchardists used Actigard™ post-harvest at the end of Season 1 that is believed to stimulate a plant defence response.

The randomness and low level expression of cankers provides little evidence of treatment differences. Overall, the canker data was too variable for accurate interpretation, but regardless of statistical analysis, it is known that cane and leader cankers are a major source of infection of Psa in kiwifruit vines. Growers were therefore advised to remove cankers soon after they were recorded and treat the cut with bactericide (e.g. Bacseal®) as part of good orchard management practice.

Data shown in Table 8 below is a summary of the number of vines with cane and leader cankers. There was no evidence of cankers re-appearing on the same vine after removal; for example Orchard 3 (Hayward) had 18 male vines with cane cankers in the grower blocks at the start of the trial in October 2012 but after these were removed there was no further occurrence of cankers on that particular vine.

Table 8: Canker occurrence in Test and Grower blocks from October 2012 – November 2013

Orchard	Variety	Season	Test		Grower	
			Cane	Leader	Cane	Leader
1	G3	1 2	0 0	2(M) 0	1(F),2(M) 2(F)	2(M) 0
2	G3	1 2	0 0	0 0	2(F) 2(F)	0 2(F)
3	Hayward	1 2	3(M), 2(F) 0	0 0	18(M) 0	0 0
4	Hayward	1 2	7(M) 1(M)	0 0	2(M) 0	0 1(M)
5	Hayward	1 2	0 0	0 1(M)	0 0	0 0

Cane and leader cankers were removed as they occurred. Each canker was recorded as a new occurrence on a different vine. Male (M) and Female (F) vines were affected in both spray treatments.

Objective 2: Effects on canopy development and yield

Leaf Nutrient Analyses

Based on data provided by Hill Laboratories, foliar concentrations of most nutrients were within the normal range for all orchards, including both grower and test blocks.

The exceptions (shown in Table 9) were:

Copper was above normal for the test treatments (all orchards). Copper was also above normal in the grower treatments but only on the Hayward orchards.

It is important to note that leaves are not routinely washed by Hill Laboratories before analysis, and elevated levels of copper may include spray residues adhering to the leaf surface.

Manganese was at or below the low end of normal for the test treatments in the G3 orchard and was tending towards low levels for the grower treated blocks on these same orchards.

Iron was marginally low in both test and grower treatments on the Hayward orchards used in the trial.

Foliar sprays were recommended across treatments in the G3 orchards in early December to correct marginal nutrient deficiencies in manganese and iron. Subsequent foliar analyses in January showed leaf nutrient balance in these orchards had been restored, but affected canopies did not fully recover. Defoliation during December was high and the canopy seemed less dense in the test blocks than the grower blocks with more yellowing and mottled leaves at harvest, though these observations were not quantified.

Table 9: Foliar copper, manganese and iron in Test and Grower blocks in November 2012

Orchard	Sampling date (2012)	Analysis		Normal Range	Level Found	
					Test	Grower
1	10 Nov	Copper	mg/kg	7-20	67	15
2	10 Nov	Copper	mg/kg	7-20	63	16
3	23 Nov	Copper	mg/kg	10-20	72	86
4	23 Nov	Copper	mg/kg	10-20	82	93
5	21 Nov	Copper	mg/kg	10-20	110	55
1	10 Nov	Manganese	mg/kg	50-150	52	66
2	10 Nov	Manganese	mg/kg	50-150	36	47
3	23 Nov	Iron	mg/kg	60-120	69	64
4	23 Nov	Iron	mg/kg	60-120	56	59
5	21 Nov	Iron	mg/kg	60-120	66	69

Other leaf parameters

Leaves were significantly smaller ($p<0.005$) in the test blocks of the G3 orchards when measurements were made in November 2012. There was a corresponding reduction in leaf chlorophyll levels which was significant in one orchard (Table 10). G3 appeared to be more sensitive to changes in nutrient status than Hayward and effects on leaves may have been the result of a direct toxicity of copper. Alternatively, there may have been antagonistic effects between elements. Copper ions have a direct effect on plant growth by their involvement in photosynthesis and can also inhibit uptake and transport of other micronutrients such as Mn, Zn and Fe by competing for binding sites (Zengin & Kirbag, 2007). Thus a deficiency in these other micronutrients can occur in the presence of excess copper. Manganese has a role in electron transport in photosystem II and a deficiency is likely to have an adverse effect on photosynthesis which will be translated into a reduced growth rate. Iron is a valuable co-factor in a multitude of cellular processes and has a role in production of reactive oxygen species which are important for defence against pathogen attack. A deficiency in iron is therefore likely to impact on growth and susceptibility to disease (Fones & Preston, 2013).

Foliar sprays applied in December to correct nutrient imbalances improved overall appearance of the canopy but did not improve differences in leaf size between the spray programmes when leaves were re-measured in January 2013. Although there was a trend towards lower chlorophyll content in trial blocks of the Hayward orchards, data were not significant, and there were no differences between treatments in leaf size (Table 8).

The test spray programme had no adverse effect on leaf shape or flowering in any of the orchards. Flower buds were similar across treatments, and were within the industry normal for G3 and Hayward (Table 10).

Table 10: Plant parameters in trial and grower blocks (November 2012 and January 2013)

Orchard	Sampling date	Leaf Area		Shape ratio		Chlorophyll reading		Flowers/bud	
		Trial	Grower	Trial	Grower	Trial	Grower	Trial	Gower
1	Nov 2012	136.8	159.8	0.66	0.66	10.2	11.5	1.5	1.7
	Jan 2013	211.2	231.1	-	-	24.3	23.2	-	-
2	Nov 2012	127.3	158.7	0.69	0.67	12.1	13.3	1.3	1.0
	Jan 2013	195.2	218.1	-	-	23.0	21.5	-	-
3	Nov 2012	183.0	180.3	0.76	0.75	21.1	23.5	2.4	2.3
	Jan 2013	191.1	197.2	-	-	34.4	32.9	-	-
4	Nov 2012	181.3	184.9	0.76	0.76	20.5	20.9	2.1	2.4
	Jan 2013	202.3	197.2	-	-	29.6	30.9	-	-
5	Nov 2012	178.9	194.0	0.72	0.72	21.8	23.2	1.7	2.2
	Jan 2013	216.0	225.0	-	-	32.8	34.1	-	-

Highlighted pairs of numbers are significantly difference (p<0.005)

Fruit harvest

Fruit from the trial blocks were harvested and graded commercially. Each test block was regarded as a different maturity area. Where possible the same process was used for grower blocks with each of the three replicates treated as separate maturity areas with harvest date determined by clearance to pick samples collected and measured by AgFirst. On the grower treatments of the three Hayward orchards fruit from beyond the 0.5ha trial area was included in the commercial pack-out and the possibility of edge effects should be considered in comparing test and grower treatment effects on yield.

The G3 orchards both had similar sized maturity areas for test and grower blocks. At one orchard a difference in maturity occurred between blocks receiving the test treatment and blocks receiving the grower treatments (Orchard 2), with harvest delayed by 10 days due to slow de-greening of fruit in the test treatment. Explanation for this is not clear, the impact of the spray programme on leaf size and canopy health may have affected fruit maturation, alternatively the delay may have been an effect of non-treatment variables, for example, temperature can affect de-greening as can light exposure. No significant differences between treatments were measured for fruit firmness, and this result was the same for all orchards (data not shown).

Across all orchard blocks, approximately 80-90% of fruit was packed as Class 1. There were no significant treatment differences in pack-out percentage of Class 1 fruit between test and grower treatments on four out of the five orchards. The biggest difference between treatments occurred on Orchard 1 where 86% of the grower treated fruit were Class 1, compared with 77% of the test spray programme fruit. Rejects and undersized fruit accounted for most of the differences on Orchard 1. There were no treatment effects or differences between Hayward and G3 orchards in Class 2 fruit, with values ranging from 3-7% for all orchards (Table 11).

Table 11: Fruit quality and class allocation for Test and Grower spray programme treatments

Orchard	Variety	Percentage of total pack-out					
		Test			Grower		
		Class 1	Class 2	Rejects & undersize	Class 1	Class 2	Rejects & undersize
1	G3	77	4	19	86	4	10
2	G3	90	4	6	88	7	5
3	Hayward	93	3	5	92	3	7
4	Hayward	93	4	4	91	3	6
5	Hayward	88	5	7	90	3	7

NB: Values are percentages of total pack-out, thus most fruit for both treatments were Class 1

Blemishes accounted for most of the fruit rejected from the G3 orchards, indicating softer skin surface for this variety that is more prone to physical damage than Hayward. While there were some blemishes on Hayward fruit; marks and shape abnormalities made up most of the reject fruit in these orchards. Test and grower treatments had similar reject rates for surface deposits and there was no spray damage on fruit from any orchard.

Although there was a high percentage of surface deposits on reject fruit from Orchard 2 none of this was caused by spray damage. None of the other orchards, G3 or Hayward had fruit damaged by spray, regardless of treatment (Table 12).

Table 12: Percentage of fruit in each reject category for Test and Grower treatments

Orchard	Variety	Treatment	Blemishes	Surface Deposits	Marks	Shape	Physical Damage	Pests	Spray damage
1	G3	Test	76	4	0	10	10	0	0
		Grower	61	6	0	11	22	0	0
2	G3	Test	38	34	5	2	21	0	0
		Grower	45	26	5	3	17	4	0
3	Hayward	Test	22	12	25	32	7	2	0
		Grower	22	17	22	32	6	1	0
4	Hayward	Test	15	17	26	34	7	1	0
		Grower	22	27	17	28	5	1	0
5	Hayward	Test	30	6	12	44	7	1	0
		Grower	34	7	14	35	9	1	0

NB: Data are means of three replicates using commercially graded fruit.

Financial returns, calculated using the Zespri on-line OGR calculator, showed differences between treatments (Table 13). For these calculations expenses for each grower were standardised to maintain the same base-line for all orchards and for ease of comparison across treatments. Financial returns show revenue as $/ha minus Psa spray costs, and do not include other expenses such as pruning, fertiliser, harvest etc. which varied between orchards. Treatment effects were inconsistent. For example, for Orchard 1 (G3), the grower treatments had more trays per hectare than the test treatment along with higher dry matter and TZG that resulted in higher return. Conversely, the return on Orchard 2 (G3) was better for the test treatment. This is mostly explained by the very low yield on one of the grower blocks on Orchard 2. This block is low-lying, prone to cold damage and had a lot of cane dieback through the season. The differences may also be explained by the delayed maturity in the test blocks that resulted in higher TZG and larger fruit size with consequent higher pay-out to the grower.

The Hayward orchards were more consistent than G3, with smaller differences between treatments and lesser difference in OGR. The exception was Orchard 3 that is currently under investigation.

Table 13: OGR comparisons for Test and Grower treatments

	G3		G3		Hayward		Hayward		Hayward	
	Test	**Grower**	**Test**	**Grower**	**Test**	**Grower**	**Test**	**Grower**	**Test**	**Grower**
TZG	0.78	0.81	0.71	0.69	0.63	0.64	0.51	0.51	0.71	0.77
Ave DM%	19.33	19.69	18.81	18.69	17.86	17.99	17.12	17.01	18.54	19.01
Average size	30.72	30.27	30.07	28.49	35.36	35.04	34.64	35.31	31.83	31.73
Forecast Payment	3.79	3.94	5.39	5.39	4.52	4.52	4.52	4.52	4.52	4.52
Canopy ha	0.37	0.37	0.42	0.31	0.52	1.82	0.46	1.94	0.62	1.15
Gross submit # trays	1,966	2,412	2,652	1,362	6,757	26,303	7,032	31,237	6,641	12,811
#trays/ha	5,266	6,519	6,264	4,394	12,993	14,452	15,288	16,101	10,944	11,189.
spray cost Psa $/ha	5,542.00	1,027.00	5,596.00	1,382.00	5,151.00	2,940.00	5,353.00	2,842.00	5,494.00	5,646.00
Financial Returns										
$/tray packed	11.53	11.83	11.17	7.61	5.02	4.94	4.68	4.53	5.55	5.73
$/ha	61,268.00	77,119.00	70,533.00	33,455.00	65,000.00	71,394.00	71,524.00	72,941.00	60,737.00	63,832.00
minus Psa spray cost$/ha	5,542.00	1,027.00	5,596.00	1,382.00	5,151.00	2,940.00	5,353.00	2,842.00	5,494.00	5,646.00
OGR Total $/ha	55726.00	76,092.00	64937.00	32,073.00	59,849.00	68454.00	66,171.00	70,099.00	55,243.00	58,186.00

Note: Values presented as financial returns are revenue minus cost of Psa spraying (other expenses are not included).

Objective 3: Impact on bud-break and plant health

Bud counts

No adverse effects of the test spray programme were observed or measured in Season 2. Similarly there were no apparent carry-over effects of the grower spray programmes on bud-break or appearance of the canopy.

The three Hayward orchards had approximately the same number of buds, ranging from 29-36 buds/m^2 and there were no treatment differences. Grower and test treatments had similar bud numbers, implying no impact of either spray programme on replacement cane growth the previous season.

There was a bigger difference between the two G3 orchards than between the Hayward orchards. There were less buds per m^2 in Orchard 2 than in Orchard 1, particularly in the test treatment vines but the difference between treatments within orchards was not significant (Figure 7).

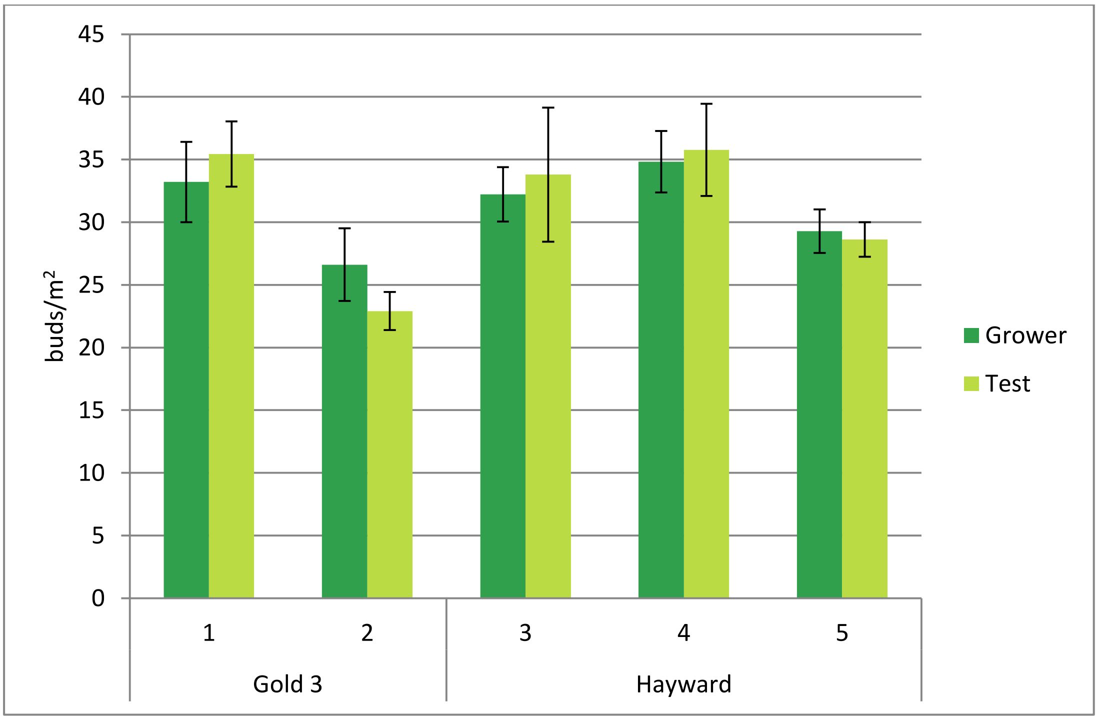


Figure 7: Bud counts per m^2 for Grower and Test spray treatments. Each count is the average and standard deviation of three replicates

Observational studies in November of the second season showed signs of calyx browning and bud-rot in Hayward Orchards 3 and 4, particularly in flower buds directly below or in close proximity to leaves heavily infested with leaf spots (Figure 8). There were no obvious visual differences in the amount of browning between test and grower spray treatments and so no further data was collected.

Figure 8: Calyx browning in Hayward flowers, showing leaf spot lesions on adjacent foliage

Copper applications

The total amount of copper applied over the first season of the trial was calculated for the test and grower spray programmes (Table 14). This was done because of concerns about excessive use of copper to control Psa, in particular in terms of phytotoxicity and yield depression. Symptoms of copper toxicity were observed on foliage of both of the G3 orchards in November 2012.

More copper was applied in the test programme than in the grower's programme. The total quantity of copper applied in the test programme exceeded the 8kg per annum maximum allowance currently recommended on Orchards 1 & 2 (both G3) and on Orchard 4 (Hayward) (Table 12). Grower applications were mostly within the 8kg limit, although Orchard 4 was just over at 8.1kg. Application of copper sulphate after harvest to enhance leaf fall added substantially to the total amount of copper applied in both test and grower blocks.

Options for reducing copper sulphate rates should be considered if a leaf fall product is being used in conjunction with a comprehensive Psa protective spray programme.

Table 14: Total copper applied over one year per ha for Test and Grower spray programmes

		Test		Grower	
Orchard		Cu applied (kg/ha)	Proportion of 8kg/ha allowance	Cu applied (kg/ha)	Proportion of 8kg/ha allowance
1	G3	8.5	106%	5.8	73%
2	G3	9.6	120%	7.7	96%
3	Hayward	3.3	41%	1.5	19%
4	Hayward	10.3	129%	8.1	101%
5	Hayward	7.0	88%	6.3	79%

Conclusions

Leaf spots were the predominant symptom recorded in Hayward orchards throughout the growing season whereas leaf spots in G3 were observed later in the summer, first appearing in February. Cane dieback was the most common symptom recorded in G3 orchards. There was a rapid build-up of cane dieback in both varieties in early Spring, particularly in male vines. The pattern of symptom development in all orchards at the beginning of the second season was similar to the previous year.

The test spray programme showed a trend for reducing cane dieback, with significant reductions in one G3 orchard. However, the test programme appeared no more effective than the grower treatments at reducing leaf spot symptoms. Overall there was little difference between test and grower spray programmes. All growers participating in this trial already had a Psa management strategy in place which was equally effective as the test programme in managing symptoms under the environmental conditions and time frame of the trial. Results may have been different if the trial had been conducted under less favourable growing conditions, therefore maintaining spray protection of orchards is advisable for keeping inoculum pressure low.

The use of copper in conjunction with other approved control options is recommended to reduce the risk of resistance build-up, environmental impacts and phytotoxicity. While it cannot be confirmed that copper was responsible for the reduction in leaf size measured in G3, the symptoms observed were typical of a nutrient imbalance that may be a result of copper accumulation in the leaf. Product incompatibility may also be a factor.

Cankers are likely to be a major source of inoculum for infection in spring. Complete removal of cankers as they were observed, followed by treatment with bactericidal compounds appeared to be a good control method for cankers. Frequent vine monitoring, and effective canker treatment is therefore a fundamental and crucial part of the Psa management process.

In conclusion, the results of this trial suggest that an intensive spray programme can play a role in reducing Psa symptoms, along with other orchard management practices. There was generally low level disease expression observed in this trial. A comprehensive spray programme, planting of cultivars with greater tolerance to Psa, improved grower management techniques and climatic conditions that are less favourable for infection have all contributed to an industry wide reduction in inoculum pressure. Although the test spray programme was more comprehensive than the grower programmes, most of the grower spray programmes compared here were relatively thorough and proved to be sufficient for the conditions experienced during the trial. The trial spray programme caused some negative impacts on vine productivity, raising awareness of the need to balance protection against Psa with managing risk to productivity. The amount of spraying required is likely to vary from year to year as environmental conditions impact on disease pressures.

References

Fones, H. and Preston, G.M (2013) The impact of transition metals on bacterial plant disease. FEMS Microbiological Reviews 37: Pages 495-519

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Acknowledgements

We thank the growers who allowed us to carry out this trial work on their orchards. Without their help and cooperation, this work would not have been possible.

We would also like to thank Carmo Saunders-Vasconcelos (Elanza Technologies Ltd) for data analysis, Odette Chesterman (MPAC) for Psa monitoring and GroPlus staff, especially Phil Mounter for his knowledge of spray diaries, and expertise with agricultural chemicals.

Appendix 1: Sprays applied in Test and Grower programmes G3 (Orchard 1)

Stage of Development	Approximate date	Product	Rate/100L	Water (L)	Number of Applications	
					Trial	Grower
Pre-Trial						
Leaf emergence	22/9/2012	Kocide® Opti™	80g	1000	1	1
Trial started: Season 1						
Shoot emergence -cane extension	5/10/2012	Kocide® Opti™ Actigard™	70g 20g	1000	1	0
Pre-flowering	12/10/2012	Nordox® Actigard™	37.5g 20g	1000	1	0
Flowering	26/10/12	Spotless®	400ml l	1000	1	0
Post-flowering	21/11/2012 29/11/2012 19/12/2012	Citrox Bioalexin®	300ml 300ml 300ml	1000 1000 1000	1 1 1	0 0 0
Post- fruit set						
60 days	10/1/2013 31/1/2013 22/2/13 15/3/13	Nordox®	37.5g 37.5g 37.5g 37.5g	1000 1000 1000 1000	1 1 1 1	0 0 0 0
	8/2/13 29/4/13	Kocide® Opti™	50g 70g	1000 1000	1 1	0 1
Post-harvest	6/5/13	Actigard™	20g	1000	1	1
	1/6/13	Copper sulphate	1000g	1000	1	1
Dormancy	24/6/13 17/7/13 6/9/13	Nordox®	55g 55g 55g	600 600 600	1 1 1	0 0 0
Season 2						
Shoot emergence cane extension	9/10/13	Kocide® Opti™	50g	1000	1	0
	18/10/13	Kocide® Opti™ Actigard™	70g 20g	1000	1	0

Note: Table includes pre-trial sprays.

Appendix 2: Sprays applied in Test and Grower programmes: G3 (Orchard 2)

Stage of Development	Approximate date	Product	Rate/100L	Water (L/ha)	Number of Applications	
					Trial	Grower
Pre-Trial						
Post-harvest	1/5/2012	Actigard™	20g	1000	1	1
Bud-break	14/9/2012	Nordox®	37.5g	1000	1	1
Leaf emergence	22/9/2012	KeyStrepto®	60g	1000	1	1
Trial Started: Season 1						
Shoot emergence - cane extension	5/10/2012	Kocide® Opti™ Actigard™	70g 20g	1000	1	0
Pre-flowering	12/10/2012	Nordox® Actigard™	37.5g 20g	1000	1	0
	26/10/2012 10/11/2012	Spotless®	400ml 400ml	1000 1000	1 1	0 1
Post-flowering	16/11/2012 29/11/2012 19/12/2012	Citrox Bioalexin®	300ml 300ml 300ml	1000 1000 1000	1 1 1	0 0 0
Post fruit set 60 days	22/12/2012 10/1/2013 31/1/2013 8/2/2014 22/2/13 28/2/2012 15/3/13	Nordox® Nordox® Nordox® Kocide® Opti™ Nordox® Kocide® Opti™ Nordox®	37.5g 37.5g 37.5g 50g 37.5g 50g 37.5g	1000 1000 1000 1000 1000 1000 1000	0 1 1 1 1 1 1	1 0 0 1 0 1 0
Post-harvest	11/5/13	Kocide® Opti™ Actigard™	90g 20g	1000	1	1
	27/6/13	Copper sulphate	125g	1000	1	1
Dormancy	28/6/13 18/7/13	Nordox®	55g 55g	600	1 1	0 0
Season 2						
Shoot emergence cane extension	18/10/13 25/10/13	Kocide® Opti™ Actigard™	50g 20g	1000	1	0

Note: Table includes pre-trial sprays

Appendix 3: Sprays applied in Test and Grower programmes: Hayward (Orchard 3)

Stage of Development	Approximate date	Product	Rate/100L	Water (L)	Number of Applications	
					Trial	Grower
Pre-Trial						
Post-harvest	13/5/2012	Nordox®	27g	1000	1	1
	17/6/2012	Nordox®	40g	1000	1	1
	4/7/2012	Nordox®	55g	350	1	1
	14/7/2012	Nordox®	55g	650	1	1
Pre bud-break	5/9/2012	Graphic® Biocide	500g	600	1	1
	23/9/2013	Nordox®	37.5g	600	1	1
Trial started: Season 1						
Shoot emergence -cane extension	5/10/2012	Kocide® Opti™/Actigard™	70g/20g	1000	1	0
	26/10/2012	Kocide® Opti™/Actigard™	70g/20g	1000	1	0
	11/10/2012	KeyStrepto™	60g	1000	0	1
	12/10/2013	Kocide® Opti™	70g	1000	1	0
Pre-flowering	17/10/2012	Nordox®/Actigard™	37.5g/20g	1000	0	1
	16/11/2012	Nordox®/Actigard™	37.5g/20g	1000	0	1
Flowering	24/11/2012	Spotless	400ml	1000	1	0
Post-flowering	1/12/2012	Kocide® Opti™	50g	1000	1	0
	26/1/2012	Kocide® Opti™	50g	1000	0	1
	17/12/2012	Citrox Bioalexin®	300ml	1000	1	0
	10/1/2013	Citrox Bioalexin	300ml	1000	1	0
Post fruit-set 60 days	30/1/2013	Nordox®	37.5g	1000	1	0
	21/2/2013	Nordox®	37.5g	1000	1	0
	15/3/2013	Nordox®	37.5g	1000	1	0
	12/4/2013	Nordox®	37.5g	1000	1	0
Post harvest	14/5/2013	Nordox®	37.5g	1000	1	0
	25/5/2013	Kocide® Opti™	50g	1000	1	1
		Actigard™	10g	1000	1	1
Dormancy	27/6/2013	Nordox®	55g	600	1	1
	19/7/2013	Nordox®	55g	600	1	1
	24/8/2013	Nordox®	55g	600	1	1
Season 2						
Shoot emergence cane extension	16/9/13	Nordox®	37.5g	1000	1	0
	29/9/2013	Nordox®	37.5g	1000	1	1
	7/10/2013	Kocide® Opti™/Actigard™	50g/20g	1000	0	1
	23/10/2013	Kocide® Opti™/Actigard™		1000	0	1
	9/11/2013	Kocide® Opti™/Actigard™				
	18/10/13	Kocide® Opti™/Actigard™	70g/20g	1000	1	0
	29/10/2013	Kasumin®	1000	1000	0	1
	30/11/2013	Kocide® Opti™	50g	1000	1	1

Note: Table includes pre-trial sprays

Appendix 4: Sprays applied in Test and Grower programmes: Hayward (Orchard 4)

Stage of Development	Approximate date	Product	Rate/100L	Water (L)	Number of Applications	
					Trial	Grower
Pre-Trial						
Post-harvest	7/6/2012	Copper sulphate	1250g	1000	1	1
	14/6/2012	Nordox®	40g	1000	1	1
	30/6/2012	Nordox®	55g	600	1	1
Pre bud-break	5/9/2012	Graphic® Biocide	500g	600	1	1
Bud-break	24/9/2012	Nordox®	37.5g	600	1	1
Trial started: Season 1						
Shoot emergence - cane extension	5/10/2012	Kocide® Opti™/Actigard™	70g/20g	1000	1	0
	26/10/2012	Kocide® Opti™/Actigard™	70g/20g	1000	1	0
	10/10/2012	KeyStrepto™	60g	1000	0	1
	29/10/2012		60g	1000	0	1
	12/10/2013	Kocide® Opti™	70g	1000	1	0
Pre-flowering	6/11/2012	Nordox®/Actigard®	37.5g/20g	1000	1	0
	20/10/2012	Nordox®/ Actigard®	37.5g/20g	1000	0	1
	19/11/201	Nordox®/Actigard™	37.5g/20g	1000	0	1
Flowering	27/11/2012	Spotless	400ml	1000	1	0
Post-flowering	10/12/2012	Kocide® Opti™	50g	1000	1	1
	19/12/2012	Citrox Bioalexin®	300ml	1000	1	0
	10/1/2013	Citrox Bioalexin®	300ml	1000	1	0
Post fruit set 60 days	27/1/2013	Kocide® Opti™	50g	1000	0	1
	22/3/2013	Kocide® Opti™	50g	1000	0	1
	30/1/2013	Nordox®	37.5g	1000	1	0
	21/2/2013	Nordox®	37.5g	1000	1	0
	15/3/2013	Nordox®	37.5g	1000	1	0
	12/4/2013	Nordox®	37.5g	1000	1	0
Post harvest	14/5/2013	Kocide® Opti™/Actigard™	50g/20g	1000	1	1
	20/6/2013	Copper sulphate	1250g	1000	1	1
Dormancy	2/7/2013	Nordox®	55g	600	1	0
	15/7/2013	Nordox®	55g	600	1	0
	7/8/2013	Nordox®	55g	600	1	0
	30/9/2013	Nordox®	55g	600	1	0
	28/8/2013	Graphic® Biocide	500ml	1000	0	1
Season 2 Bud break	16/9/2013	Nordox®	37.5g	1000	0	1
Shoot emergence cane extension	2/10/2013	Nordox®	37.5g	1000	1	1
	13/10/13	Kocide® Opti™/Actigard™	70g/20g	1000	1	0
	24/10/13	Kocide® Opti™/Actigard™			0	1
	11/11/2013	Kocide® Opti™/Actigard™			0	1
	29/10/2013	Kasumin®	500ml	1000	0	1

Note: Table includes pre-trial sprays

Appendix 5: Sprays applied in Test and Grower programmes: Hayward (Orchard 5)

Stage of Development	Approximate date	Product	Rate/100L	Water (L)	Number of Applications: Trial	Number of Applications: Grower
Pre-Trial						
Post-harvest	4/4/2012	Kocide® Opti™	30g	1000	1	1
	28/6/201	Copper sulphate	625g	1000	1	1
	9/7/2012	Kocide® Opti™	90g	1000	1	1
	9/8/2012	Kocide® Opti™	70g	1000	1	1
	31/8/2012	Kocide® Opti™	70g	1000	1	1
Bud-break	13/9/2012	Kocide® Opti™	83g	1000	1	1
Leaf emergence	19/9/2012	Kocide® Opti™	70g	1000	1	1
Trial started: Season 1						
Shoot emergence - cane extension	5/10/2012	Kocide® Opti™/Actigard™	70g/20g	1000	1	0
	19/10/2012	Kocide® Opti™/Actigard™	70g/20g	1000	0	1
	26/10/201	Kocide® Opti™/Actigard™	70g/20g	1000	1	0
	5/10/2012	Kocide® Opti™	70g	1000	0	1
	12/10/2012	Kocide® Opti™	70g	1000	1	0
	1/11/2012	KeyStrepto®	60g	1000	0	1
Pre-flowering	6/11/2012	Kocide® Opti™/Actigard™	60/20g	1000	0	1
	6/11/2012	Nordox®/Actigard™	37.5g/20g	1000	1	0
Flowering	23/11/12	Spotless®	400ml	1000	1	0
Post-flowering	4/12/2012	Citrox Bioalexin®	300ml	1000	1	0
	4/12/2012	Kocide® Opti™	40g	1000	0	1
	11/12/2013	Kocide® Opti™	40g	1000	0	1
	14/12/2012	Kocide® Opti™	50g	1000	1	0
	20/12/2012	Kocide® Opti™	40g	1000	0	1
	10/1/2013	Kocide® Opti™	40g	1000	0	1
	12/2/2013	Kocide® Opti™	40g	1000	0	1
Post- fruit set 60 days	10/1/2013	Nordox®	37.5g	1000	1	0
	31/1/2013	Nordox®	37.5g	1000	1	0
	20/2/2013	Nordox®	37.5g	1000	1	0
	15/3/2013	Nordox®	37.5g	1000	1	0
	12/4/13	Nordox®	37.5g	1000	1	0
	16/3/13	Kocide® Opti™	40g	1000	0	1
	9/4/13	Kocide® Opti™	40g	1000	0	1
Post-harvest	13/5/ 13	Kocide® Opti™/Actigard™	50g/20g	1000	0	1
	16/5/2013	Actigard ™	20g	1000	1	0
	11/6/2013	Kocide® Opti™	70g	1000	0	1

	25/6/13	Copper sulphate	625g	1000	1	1
Dormancy	2/7/13 19/7/13 7/8/13 6/9/2013	Nordox®	55g 55g 55g 55g	600 600 600 600	1 1 1 1	0 0 0 0
	15/7/2013 9/8/2013 3/9/2013	Kocide® Opti™	80g 80g 80g	1000 1000 1000	0 0 0	1 1 1
Season 2						
Bud break	18/9/2013	Kocide® Opti™	70g	1000	1	1
Shoot emergence cane extension	3/10/13 29/10/2013	Kocide® Opti™	70g 50g	1000 1000	0 0	1 1
	2/10/2013	Nordox®	37.5g	1000	1	0
	16/10/2013	Kocide® Opti™/Actigard™	60g/33g	1000	1	1
	24/10/2013	KeyStrepto®	60g	1000	1	0
	2/11/2013	Actigard™	20g	1000	1	1
Flowering	29/11/2013	Kocide® Opti™	50g	1000	1	1

Note: Table includes pre-trial sprays.