Eutypa dieback survey Limestone Coast 2019

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Summary

- A survey was undertaken in the Limestone Coast vineyards of Coonawarra, Wrattonbully and Mt Benson/Robe to determine the incidence of grapevine trunk disease in November 2019.
- The overall mean incidence of dieback and eutypa foliar symptoms was 52 and 11%, respectively.
- The incidence of dieback was greatest in Wrattonbully (64%), followed by Coonawarra (57%) and Mt Benson/Robe (34%). In terms of foliar symptoms of eutypa dieback, Coonawarra had the greatest incidence (16%), compared with Wrattonbully (7.5%) and Mt Benson/Robe (1.2%).
- Over the past 7 years, the annual increase in incidence of dieback was 1% in Coonawarra and 7.5% in Wrattonbully, this difference most likely due to the greater amount of vineyard rejuvenation and pruning wound protection being undertaken in Coonawarra compared with Wrattonbully.
- Dieback and eutypa foliar symptoms were observed in vines as young as 4 years, the youngest recorded with foliar symptoms in Australia. It is likely these vines were infected in the first year of production, highlighting the importance of early intervention with wound protection.
- The incidence of blocks in Limestone Coast with 100% dieback was 5% in 2012 and has increased to 20% in 2019.
- Cabernet Sauvignon and Shiraz had the highest incidence of disease symptoms and Merlot and Chardonnay were recorded with the lowest incidence.
- Rootstocks and clones varied in disease incidence, but due to limited representative sample sizes, results were inconclusive, and further investigation is required.
- There were no differences in disease symptoms evident between spur-pruning management styles: detailed, semi-detailed and hedged, highlighting the importance of applying other disease management strategies.
- Overall, blocks with wound protection had only slightly lower disease symptoms than those with no wound protection. Results showed that commencing wound protection on infected, mature vines is unlikely to have any impact, and blocks exposed to infection for as little as the first 2 years of production are still vulnerable to developing disease. Wound protection programs commencing from planting led to considerably less symptoms than when protection was delayed.
- There was only a small reduction in disease incidence for blocks that had been remediated. The height of cuts or incidence of trunks remaining with visible infection were not available, but may have influenced the effect of remedial surgery on disease incidence.
- There was little difference in between blocks with and without frost protection.

Introduction

Grapevine trunk diseases (GTDs) such as eutypa and botryosphaeria dieback contribute to grapevine decline, reducing productivity and longevity, causing considerable economic loss and threatening the sustainability of the Australian wine industry which contributes $19.7 billion to the Australian economy. It was estimated that eutypa dieback cost South Australian growers up to $2800 per hectare through lost production (Wicks and Davies 1999) and GTDs were ranked in the top six pest and diseases for the viticulture industry (Scholefield and Morrison 2010).

The eutypa dieback pathogen, *Eutypa lata*, infects vines through pruning wounds and colonises woody tissue at a rate of up to 50 mm/year (Sosnowski et al. 2007b) causing dieback of cordons and trunks. In cross-section, diseased wood appears as dark wedge-shaped tissue. The fungus produces toxic metabolites which are translocated to the foliage, causing stunted shoots, necrotic and distorted leaves, reduced bunch size and uneven ripening. Symptoms of botryosphaeria dieback, caused by species of the Botryosphaeriaceae family of fungi, are similar to those of eutypa dieback with the exception of the characteristic foliar symptoms. Spurs often show reduced growth followed by die back of cordons and trunks, with cross-sectional staining observed in infected cordons and trunks.

The occurrence of eutypa dieback in the Limestone Coast wine region has been reported over the past 40 years (Wicks 1975, Highet & Wicks 1998, Sosnowski et al. 2010, 2011). In 2007, a survey of 92 blocks in Mt Benson reported foliar symptoms of eutypa dieback in only 2 blocks, with three symptomatic vines in total (Sosnowski et al. 2010). In 2012, an intensive survey of 207 blocks in the Coonawarra and Wrattonbully sub-regions of the Limestone Coast reported dieback symptoms in 92% of blocks and foliar symptoms of eutypa dieback in 75% of all blocks surveyed (Sosnowski et al. 2012). Trunk disease is believed to have a significant effect on grape production, particularly in older vineyards, where it has had longer to establish. More recently, anecdotal evidence suggests that the prevalence of trunk disease is rising, with increased reports of dieback and foliar symptoms in the region, in addition to the many other regions of Australia (Sosnowski and Wicks 2012). There is now an opportunity revisit the blocks surveyed in 2012, as well as new blocks planted in the last decade, to determine the progress of trunk disease and current status in the Limestone Coast, which will facilitate implementation of strategies to combat the problem.

Over the past decade, research in Coonawarra and elsewhere has led to effective methods of managing trunk disease by removing existing infection using remedial surgery and protecting pruning wounds from new infection (Sosnowski et al. 2009, 2010, Ayres et al. 2017). It is envisaged that determining the extent of the problem will indicate its future impact, and encourage the industry to adopt appropriate methods to manage trunk disease, not only in the Limestone Coast but in regions across the country.

The aims of this project are to:

- Survey Limestone Coast vineyards in Coonawarra, Wrattonbully and Mt Benson/Robe for the incidence of grapevine trunk disease.
- Compile and analyse the data to provide a report of the current status of grapevine trunk disease across a range of varieties and vine ages, and provide some insight into the effectiveness of disease management systems.

Methods

The survey team (Figure 1a) assessed 342 vineyard blocks in Coonawarra (217), Wrattonbully (46) and Mt Benson/Robe (79) from 4-8 November 2019. Vines ranged in age from 3 to 107 years and included 12 varieties with Cabernet Sauvignon and Shiraz the most common. The survey included blocks that had previously been surveyed in 2012 (Coonawarra and Wrattonbully) and in 2007 (Mt Benson/Robe). Of those, 17 blocks were removed in Coonawarra, six in Wrattonbully and 12 in Mt Benson/Robe, between the surveys. In 2019, new blocks were introduced for the survey, generally younger vineyards aged between 3 and 9 years, to better reflect the current average age of vineyards across the regions. There were 83 new blocks in Coonawarra, one in Wrattonbully and four in Mt Benson/Robe.

In each block, 200 vines were visually assessed (Figure 1b) for dieback (two or more dead spurs or dead cordon) and foliar symptoms of eutypa dieback. The number of vines with symptoms was counted and the incidence calculated.

In addition, information that included variety, age, pruning system, own-roots or rootstock, wound protection, reworking and frost protection was collected for each vine block from growers and vineyard managers.

Pruning management systems of cordon-trained vines were as follows:
Detail – hand pruning of vines to a set bud number, most spurs spaced apart 10-15 cm and pruned to 2 buds per spur.
Semi-detail – vines machine pruned and then hand pruned leaving varying spur and bud numbers per vine. Generally, spurs may vary from 1-3 buds each.
Hedge – vines machine pruned and skirted around posts. Downward facing shoots pruned by hand, spurs can be any length depending on where they grew from in the canopy the previous year.

Data were analysed by linear regression, and coefficients of determination (R^2) were calculated using Microsoft® Excel. Results were presented graphically as scatter plots.

Figure 1. a. Survey team (from left) Mark Sosnowski, Michelle Malone, Matthew Ayres and Sarah Bird and b. visual assessment of vines.

Results

Dieback symptoms (Figure 2a-d) were observed in 329 (96%) of the 342 blocks surveyed. In individual vineyards, the incidences ranged from 0.5 to 100%. Foliar symptoms characteristic of eutypa dieback (Figure 2d-g) were observed in 262 (77%) of the 342 blocks surveyed. In individual vineyards, the incidences ranged from 0.5 to 78%. The overall mean incidence of dieback and foliar symptoms in the Limestone coast survey was 52 and 11%, respectively.

Figure 2. Grapevine trunk disease symptoms observed in Limestone Coast vineyards in November 2019; (a) dead spurs, (b-c) dead arms, and (d-g) foliar symptoms of eutypa dieback

During the survey, tight wrapping of cordons was also observed in some vineyards (Figure 3a-d). Wires were embedded in the twisted cordon wood and cordons had cankers, dieback and, in some cases, foliar symptoms of eutypa dieback. In a few vineyards, new canes were wrapped over dead, infected cordons, so that new pruning wounds were located very close to fruiting bodies of the eutypa dieback pathogen (Figure 3e-f).

Figure 3. a-d. Tight wrapping of cordons around wires observed in several vineyards and associated with dieback symptoms and e-f. new canes wrapped over dead, infected cordons.

Cankers and dieback were observed extending from pruning wounds on cordons (Figure 4a-b). Some vineyards were observed with very large wounds caused by pruning saws (Figure 4c-d) and hedged pruned vines were left with many wounds (Figure 4e-f).

Figure 4. a-b. Cankers and dieback extending along cordon from pruning wounds (indicated with red arrows), c-d. large wounds caused by pruning saws and e-f. the many wounds remaining following hedge pruning.

There were also many examples of proactive management of eutypa dieback, with the use of paints to protect large wounds (Figure 5a-b), layering (Figure 5c) and remedial surgery (Figure 5d) to renew infected vines.

Figure 5. Proactive trunk disease management of grapevines observed in vineyards. a-b. wound protection of large wounds with paint, c. layering and reworking to replace diseased vines.

Sub-region

Table 1 summarises the average age, mean incidence of dieback and eutypa foliar symptoms for the three sub-regions surveyed in 2007, 2012 and 2019.

In Coonawarra, mean incidence of dieback and foliar symptoms increased from 51-83% and 9-25%, respectively, with the average age of vines increasing from 25 to 32 years between the two surveys. However, when including the 83 new vineyard blocks, with an average age of 23 years (2 years less than in 2012), dieback and foliar symptoms were 57 and 16%, respectively, reflecting 6% increase in dieback and 7% increase in foliar symptoms, regardless of age, over the 7 years between surveys.

In Wrattonbully, mean incidence of dieback and foliar symptoms increased from 10-64% and 1.4-7.5%, respectively, with the average age of vines increasing from 14 to 21 years between the two surveys.

In Mt Benson/Robe, only foliar symptoms were assessed in 2007, and mean incidence of foliar symptoms increased from 0.02-1.2%, respectively, with the average age of vines increasing from 25 to 32 years, between the two surveys. In 2019, mean incidence of dieback was 34%, with an average vine age of 22 years.

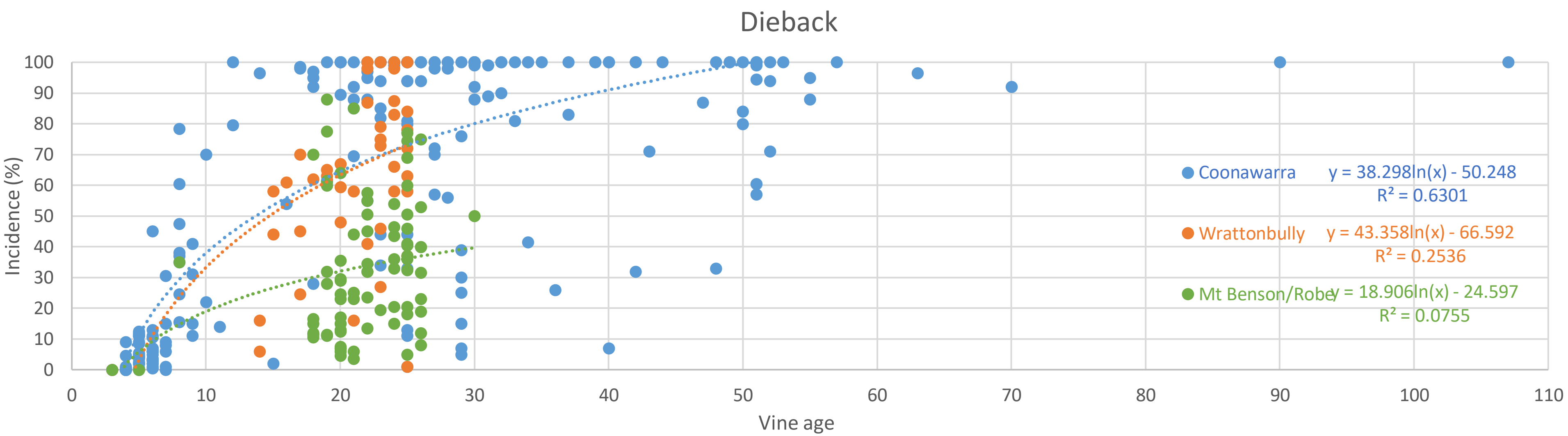
In 2019, with similar average vine age ranging between 21 and 23 years, incidence of dieback was greatest in Wrattonbully (64%), compared with Coonawarra (57%) and Mt Benson/Robe (34%). In terms of foliar symptoms of eutypa dieback, Coonawarra had the greatest incidence (16%), compared with Wrattonbully (7.5%) and Mt Benson/Robe (1.2%).

Table 1. Limestone Coast sub-regions surveyed in 2007, 2012 and 2019, with average age of vines, average incidence of eutypa dieback and foliar symptoms.

Sub-region	2012			2019		
	Ave age (y)	Dieback (%)	Foliar (%)	Ave age (y)	Dieback (%)	Foliar (%)
Coonawarra	25	50.9	9.4	32[1]	83.0[1]	24.5[1]
				23[2]	56.9[2]	15.8[2]
Wrattonbully	14	10.2	1.4	21	63.8	7.5
	2007			2019		
Mt Benson/Robe	10	na	0.02	22	34.0	1.2

[1]Original blocks only
[2]Original and new blocks combined

When comparing incidence of dieback with vine age between the three sub-regions, logarithmic regression curves provided the highest coefficients of determination (Figure 6). Incidence of dieback increased with age at similar rates in Coonawarra and Wrattonbully, and lower rates of increase occurred in Mt Benson/Robe. For foliar symptoms of eutypa dieback, linear regression curves provided the highest coefficients of determination, with the greatest rate of increase in Coonawarra and the least in Mt Benson/Robe.



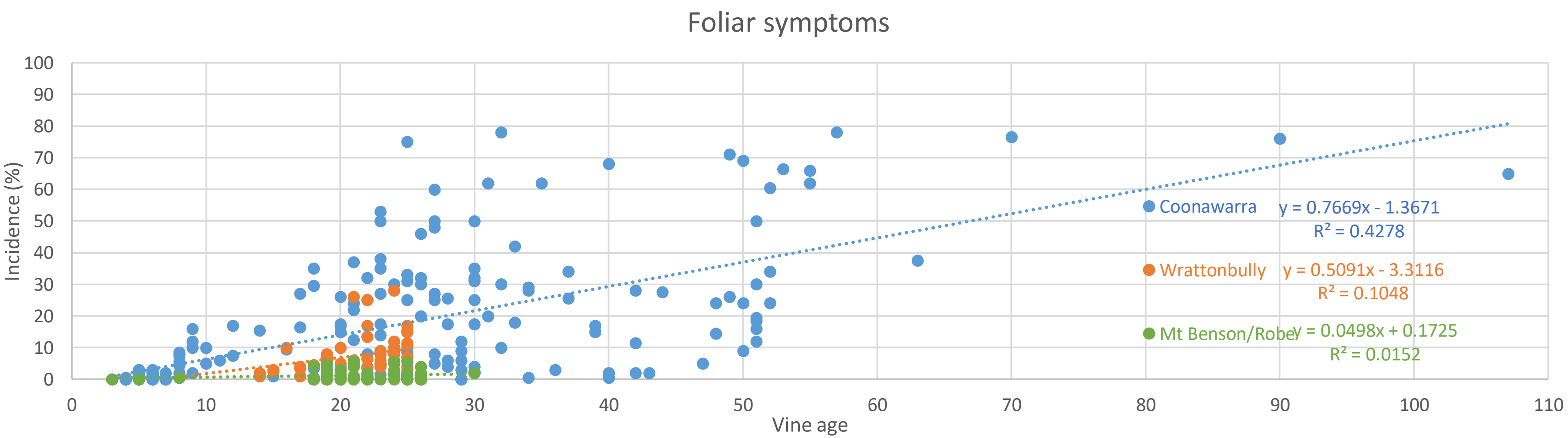


Figure 6. Scatter plots showing the relationship between vine age and incidence of dieback and eutypa foliar symptoms in the Limestone Coast sub-regions surveyed. Correlation curves of best fit were logarithmic for dieback and linear for foliar symptoms. Assessments were undertaken in November 2019.

Vine age

The youngest vines with dieback were 4 years of age, with up to 9% incidence recorded in five blocks (Figure 6). Ten-year-old vines were recorded with up to 80% incidence of dieback, and 100% incidence recorded in some blocks from 12 years of age. The greatest rate of increase in dieback symptoms occurred in blocks with vines aged between 3 and 20 years, and 37 (80%) of the 46 blocks over 30 years of age, were recorded with over 80% incidence. Of all 343 blocks assessed, 69 blocks (20%) were recorded with 100% incidence of dieback.

The youngest vines with foliar symptoms of eutypa dieback were 4 years of age, with 0.5% incidence recorded in one block (Figure 6). The maximum incidence of foliar symptoms increased to 78% in 32 year old vines.

Variety

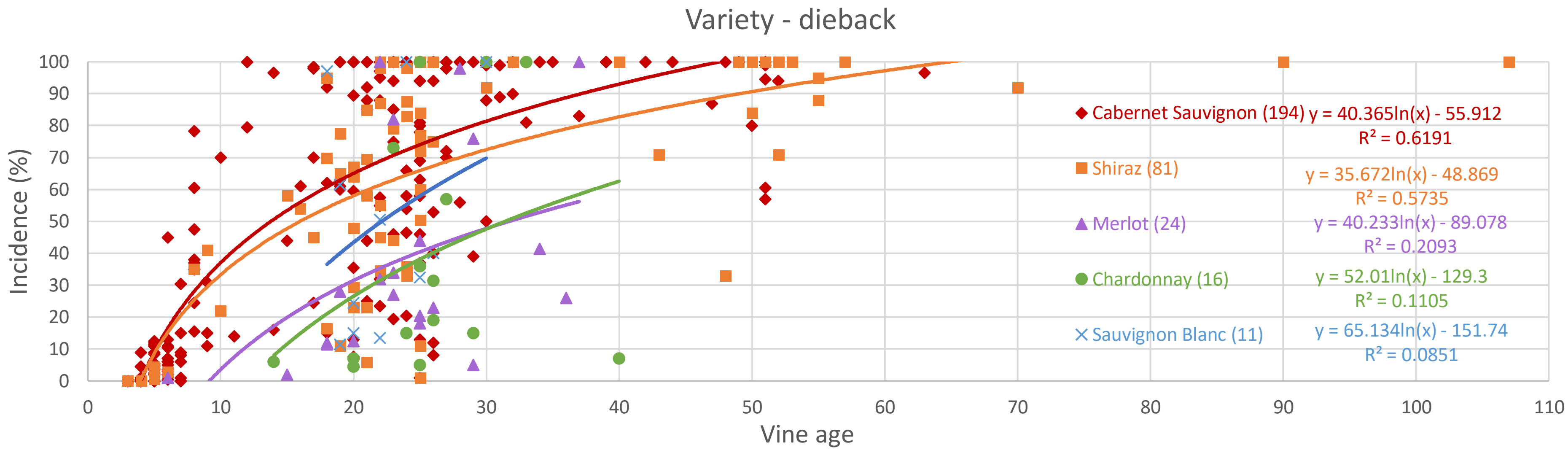
The percentage of blocks assessed for each variety was generally aligned with the proportion of area planted to each variety in the three survey sub-regions (Table 2). Cabernet Sauvignon and Shiraz were the most commonly planted varieties, represented by 57 and 24% of all blocks assessed, respectively. All other varieties were each represented by less than 7% of all blocks.

Table 2. Grape varieties surveyed, area and proportion planted in the Coonawarra, Wrattonbully, Mt Benson/Robe sub-regions (SA Winegrape Crush Survey 2019, Wine Australia), number and proportion of blocks surveyed in November 2019, and average vine age.

Variety	Area (ha)	% area planted	Blocks surveyed				% blocks surveyed	Ave. vine age (y)
			C/warra	W/bully	Mt B/R	Total		
Cabernet Sauvignon	5183	54.8	149	22	23	194	56.6	20
Shiraz	2270	24.0	42	17	22	81	23.6	26
Merlot	737	7.8	11	2	10	23	6.7	24
Chardonnay	568	6.0	6	3	7	16	4.7	26
Sauvignon Blanc	250	2.6	3	0	8	11	3.2	22
Pinot Gris	157	1.7	0	1	2	3	0.9	19
Pinot Noir	152	1.6	0	1	1	2	0.6	22
Riesling	79	0.8	5	0	1	6	1.7	29
Semillon	27	0.3	0	0	3	3	0.9	23
Cabernet Franc	22	0.2	1	0	1	2	0.6	27
Petit Verdot	17	0.2	1	0	0	1	0.3	29
Viognier	na	na	0	0	1	1	0.3	20
Total	9462	100				343	100	24

When comparing incidence of dieback with vine age between the varieties, logarithmic regression curves provided the highest coefficients of determination (Figure 7). The rate of increase in incidence of dieback was similar for the four most common varieties assessed. However, incidence increased earlier for Cabernet Sauvignon and Shiraz than for Merlot and Chardonnay. Sauvignon Blanc, although only represented by 11 blocks, had a higher rate of increase in dieback than the four previously mentioned varieties, but symptoms were generally not evident until at least 19 years of age. All blocks older than 40 years were Cabernet Sauvignon or Shiraz.

For foliar symptoms of eutypa dieback, linear regression curves provided the highest coefficients of determination. Shiraz had a greater rate of increase in incidence of foliar symptoms than Cabernet Sauvignon. Chardonnay had a greater rate of increase in incidence than Merlot, but both developed symptoms later than Shiraz and Cabernet Sauvignon. Very few foliar symptoms were recorded on Sauvignon Blanc.



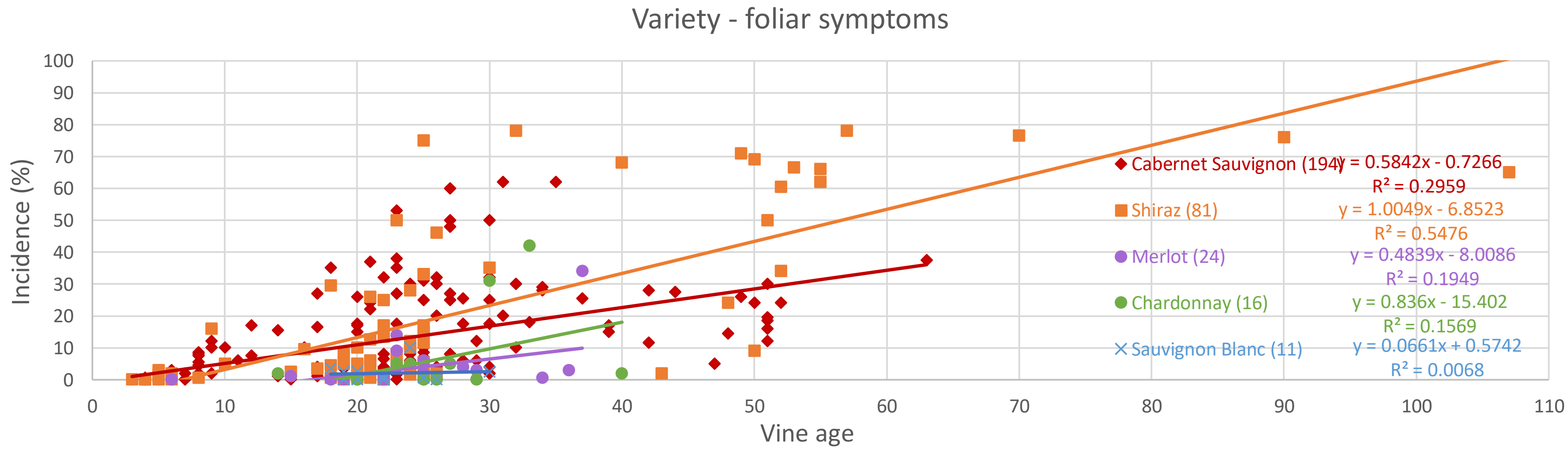
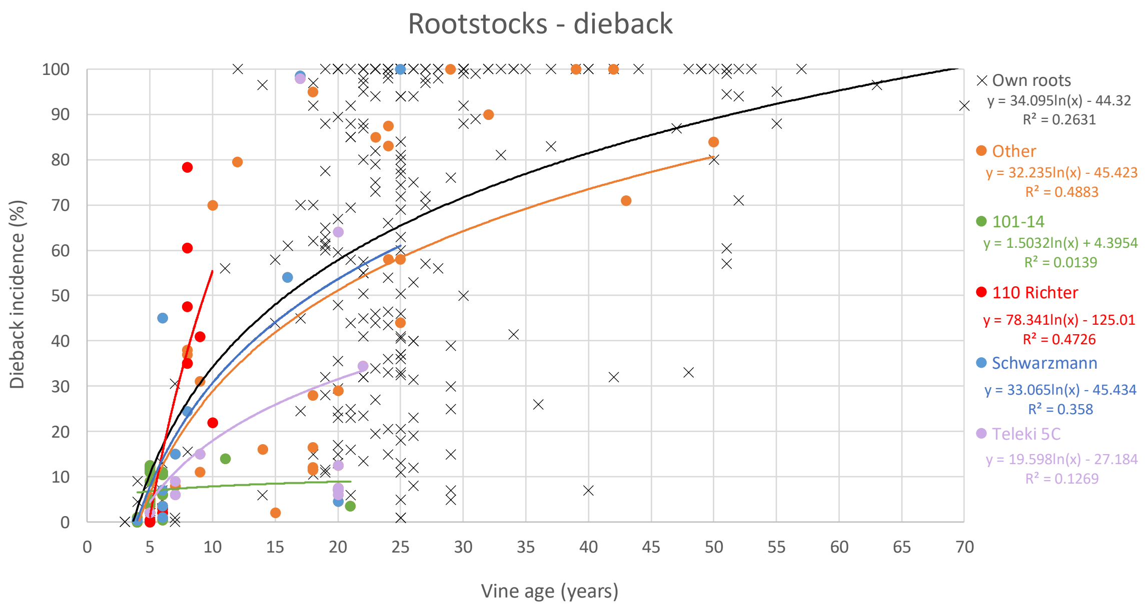


Figure 7. Scatter plots showing the relationship between vine age and incidence of dieback and eutypa foliar symptoms on the five most common varieties surveyed. Correlation curves of best fit were logarithmic for dieback and linear for foliar symptoms. Assessments were undertaken in November 2019.

Rootstocks

Of the blocks assessed where rootstock information was available, 245 were own-rooted and 97 planted on rootstocks across all varieties, with 20 on 101-14, 13 on Schwarzmann, and 11 each on 110 Richter and Teleki 5C, with all others represented by less than three blocks or unknown.

Blocks varied greatly for both dieback and foliar symptom incidence, and logarithmic and linear regressions provided the greatest coefficients of determination, respectively (Figure 8). Blocks planted on 101-14 and Teleki 5C had the lowest dieback and foliar symptom incidence compared with other rootstock and own-rooted blocks, however, coefficients of determination were very low (R^2<0.13) due to low representative sample numbers and blocks being only aged up to 22 years. Blocks planted on Schwarzmann and 'other' rootstocks had similar incidence of dieback (R^2=0.26-0.48) but slightly lower incidence of foliar symptoms (R^2=0.22-0.27) compared to blocks planted on own-roots. Blocks planted on 110 Richter were only aged up to 10 years, but had the greatest incidence of dieback and foliar symptoms in that age group (R^2=0.47 and 0.35, respectively).



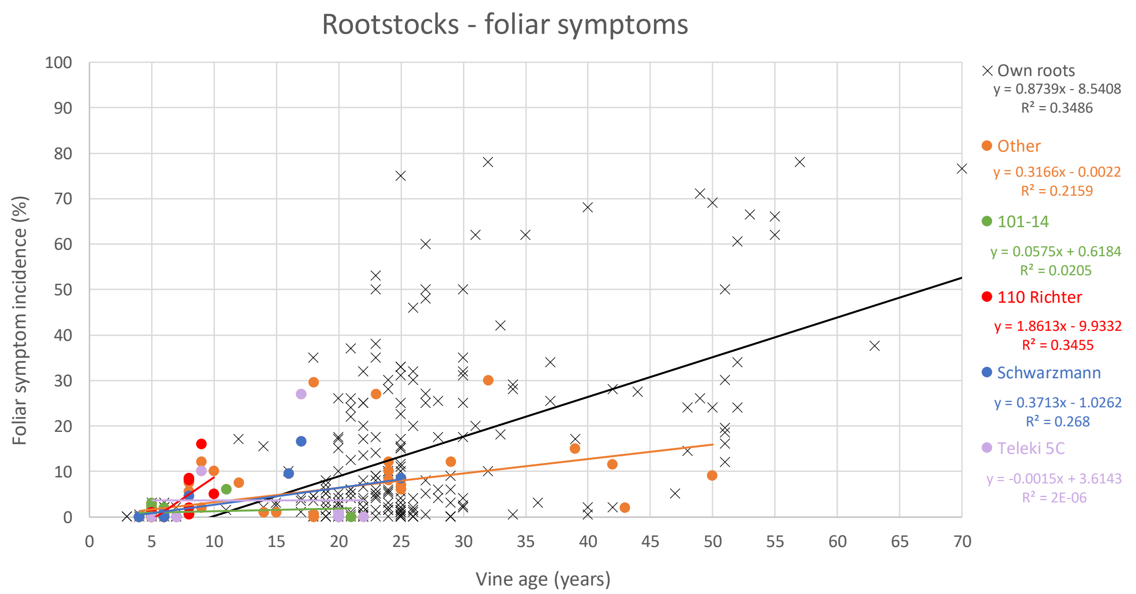
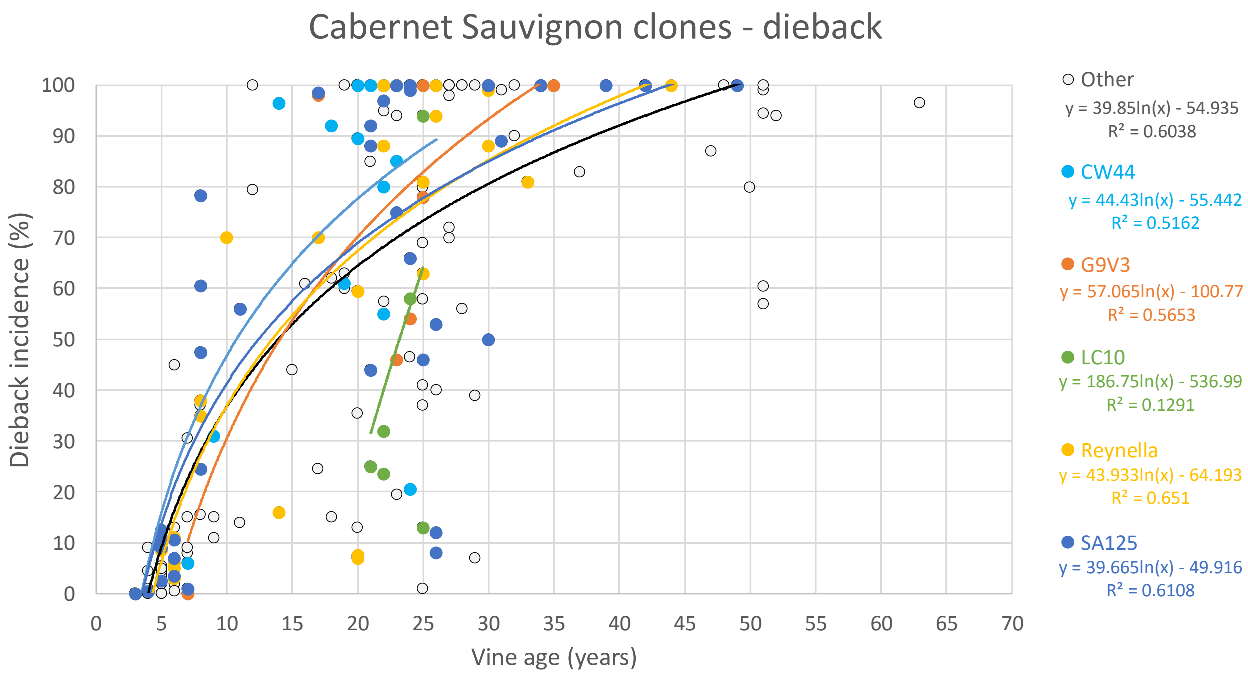


Figure 8. Scatter plots showing the relationship between vine age and incidence of dieback and eutypa foliar symptoms on grapevines planted on rootstocks or own roots. Blocks planted on own roots are indicated with an x and blocks planted on rootstocks are indicated by the different coloured dots. Logarithmic and linear regressions provided the greatest coefficients of determination for dieback and foliar symptom incidence, respectively.

Clones

Of the Cabernet Sauvignon blocks where clone information was available, 42 were SA125, 26 were Reynella, 15 were CW44, seven each were G9V3 and LC10, with all others represented by less than three blocks or unknown.

Blocks varied greatly for both dieback and foliar symptom incidence, and logarithmic and linear regressions provided the greatest coefficients of determination, respectively (Figure 9).There were no differences between most clones of Cabernet Sauvignon for dieback or foliar symptoms of eutypa dieback (R^2=0.52-0.65), other than LC10 (R^2=0.13) which was represented by a small sample size and age range.



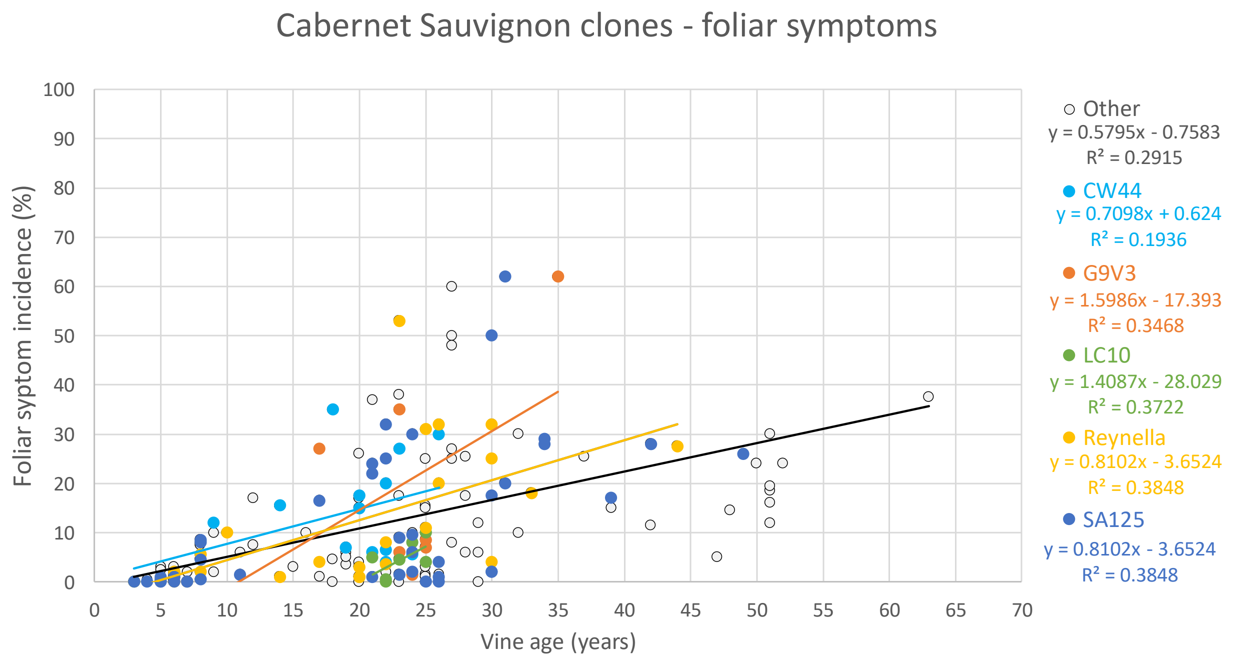


Figure 9. Scatter plots showing the relationship between vine age and incidence of dieback and eutypa foliar symptoms on Cabernet Sauvignon clones denoted by the different coloured dots. Logarithmic and linear regressions provided the greatest coefficients of determination for dieback and foliar symptom incidence, respectively.

Furthermore, when plotting only Cabernet Sauvignon clone SA125 on the various rootstocks some clustering is evident which may suggest an interaction between clone and rootstock (Figure 10). However, due to the limited number of representative samples in the survey, it is not possible to confirm this statistically.

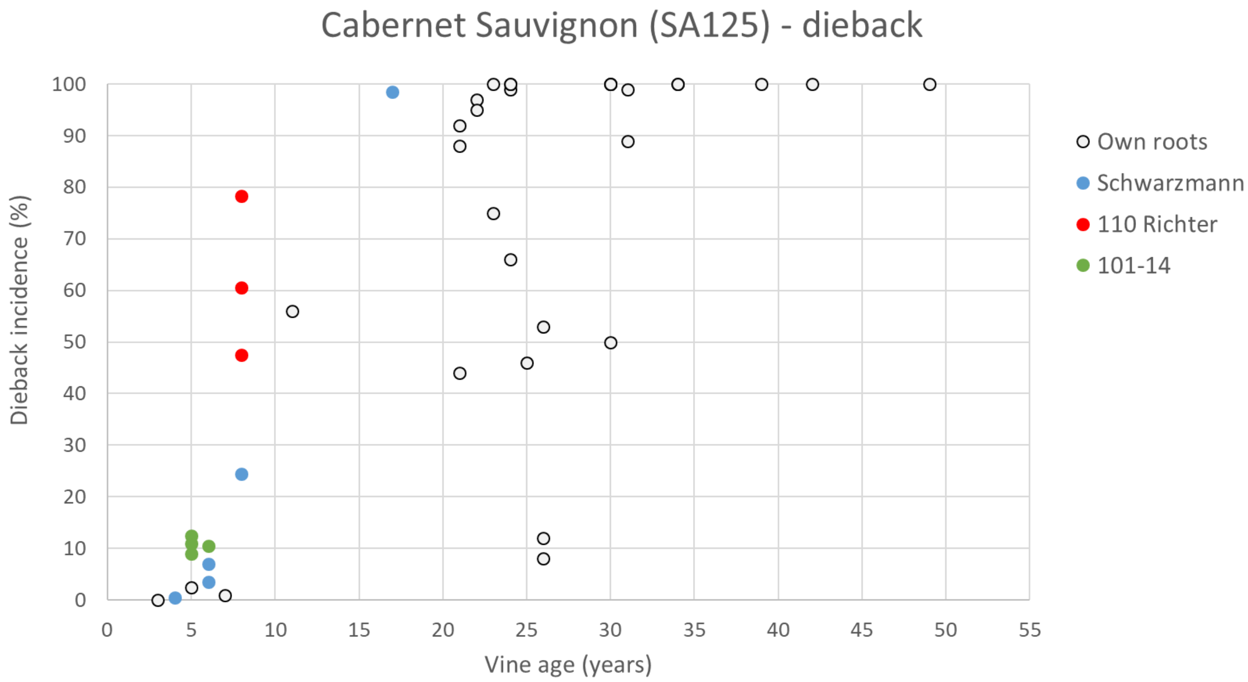
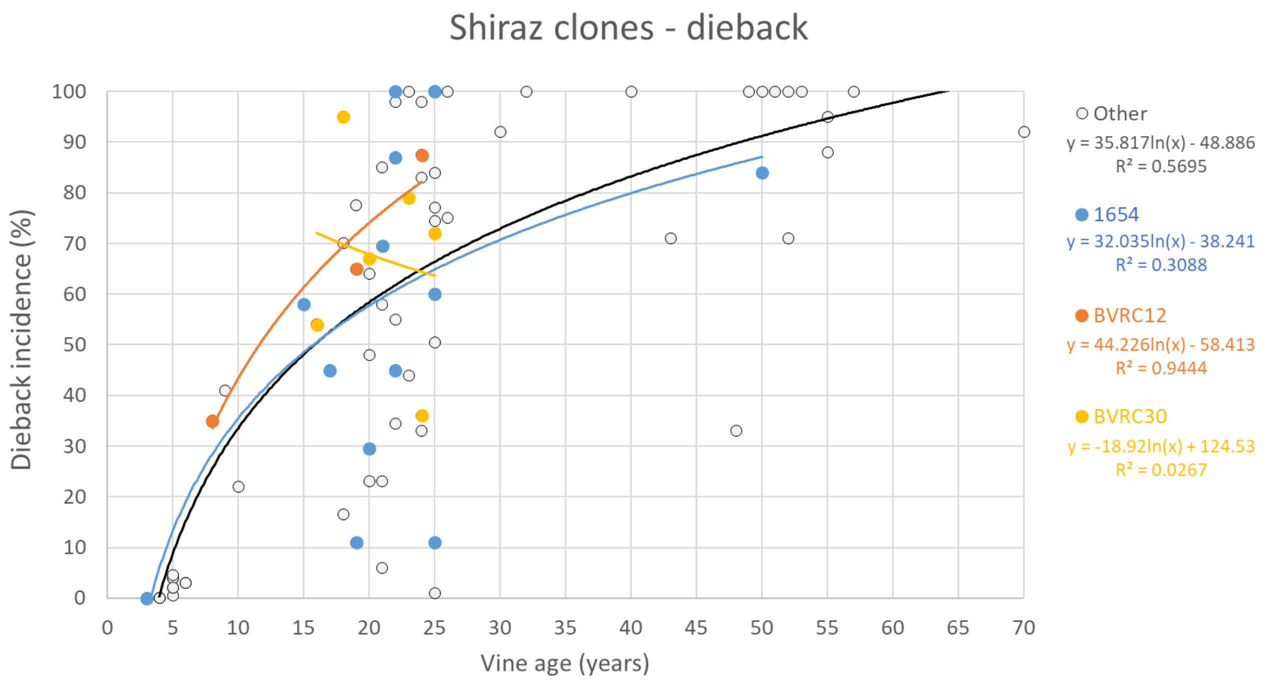


Figure 10. Scatter plot showing the relationship between vine age and incidence of dieback and eutypa foliar symptoms on Cabernet Sauvignon clone SA 125, with rootstocks denoted by the different coloured dots.

Of the Shiraz blocks where clone information was available, 14 were 1654, six were BVRC 30 and three were BVRC 12, with all others represented by less than three blocks or unknown.

Blocks varied greatly for both dieback and foliar symptom incidence, and logarithmic and linear regressions provided the greatest coefficients of determination, respectively (Figure 11). Shiraz clone BVRC 12 (R^2=0.94) had greater incidence of dieback than all other clones. Shiraz clone 1654 had lower incidence of foliar symptoms compared with other clones, but with very low coefficient of determination (R^2=0.07). Shiraz clone BVRC 30 had a negative slope for both dieback and foliar symptom incidence, with very low coefficient of determination (R2=0.03 and 0.08, respectively).



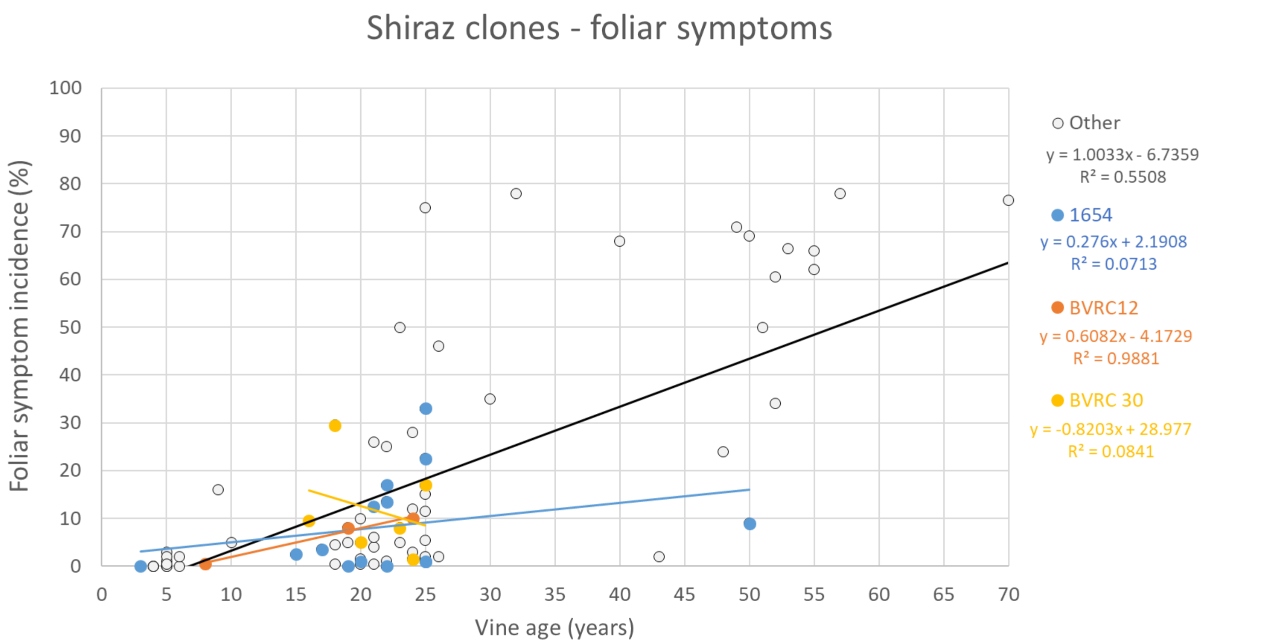
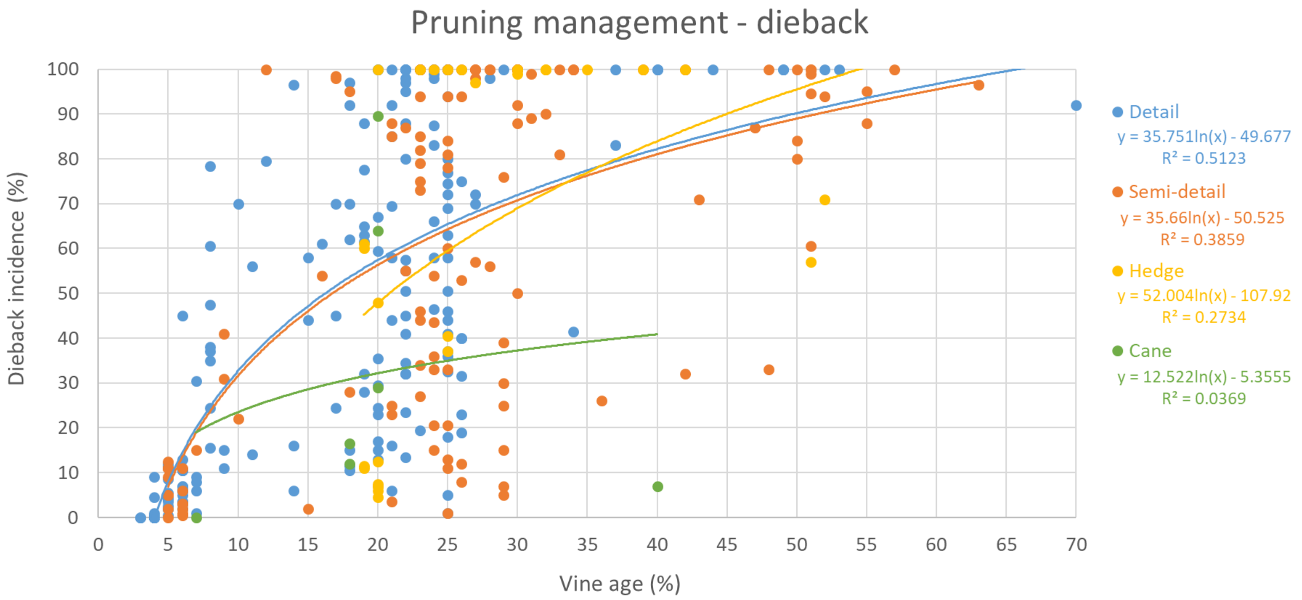


Figure 11. Scatter plots showing the relationship between vine age and incidence of dieback and eutypa foliar symptoms on Shiraz clones, denoted by the different coloured dots. Logarithmic and linear regressions provided the greatest coefficients of determination for dieback and foliar symptom incidence, respectively.

Pruning management

Of the blocks where the pruning management information was available, 176 were detail pruned, 123 semi-detailed pruned, 29 hedge pruned and only seven blocks were cane-pruned.

Blocks varied greatly for both dieback and foliar symptom incidence, and logarithmic and linear regressions provided the greatest coefficients of determination, respectively (Figure 12). There were no differences between the spur pruning management styles (detailed, semi-detailed and hedged) for dieback or foliar symptoms of eutypa dieback (R^2=0.27-0.51). Cane-pruned blocks had lower incidences of dieback and foliar symptoms than spur-pruned blocks, however, coefficient of determination was very low (R^2=0.04 and 0.009, respectively) due to the low number of representative samples.



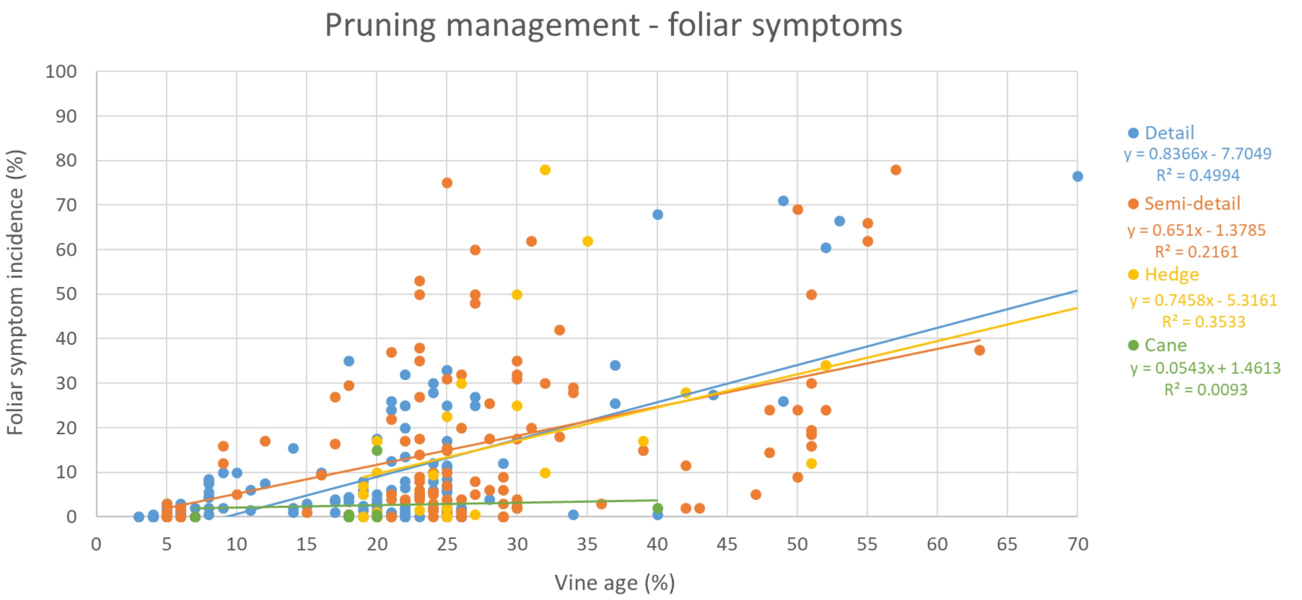
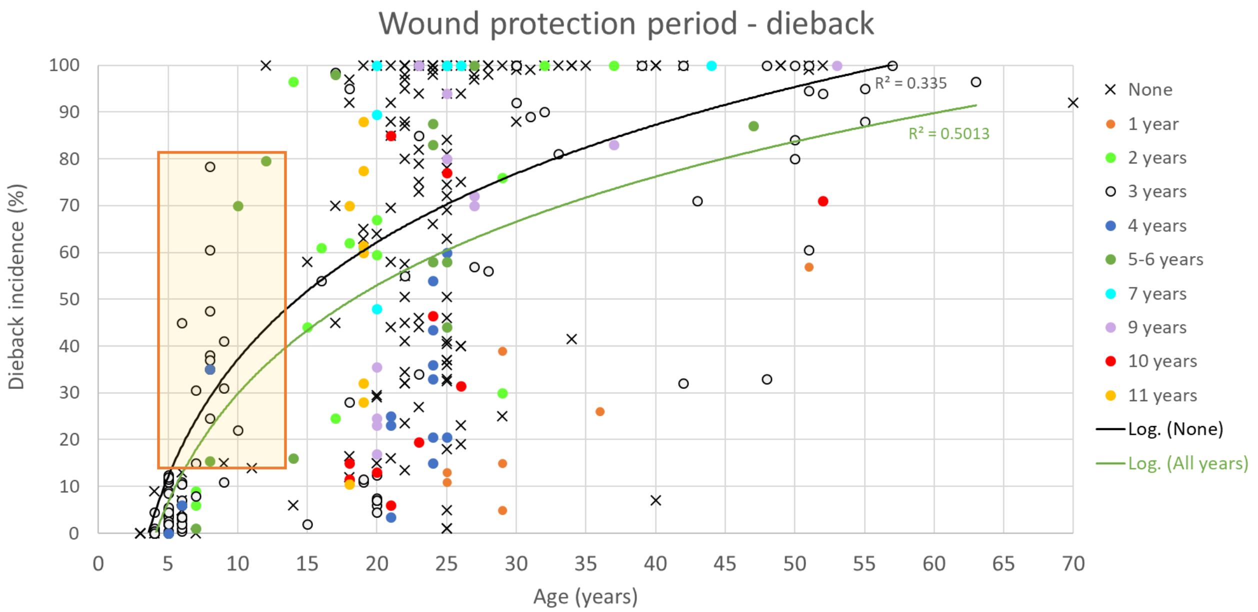


Figure 12. Scatter plots showing the incidence of dieback and foliar symptoms of eutypa dieback with vine age. Pruning management systems are indicated by the different coloured dots. Logarithmic and linear regressions provided the greatest coefficients of determination for dieback and foliar symptom incidence, respectively.

Wound protection

Of the blocks where post-pruning wound protection information was available, 199 blocks had been treated with wound protection, commencing up to 11 years earlier, and 141 blocks had never had wound protection applied. When only comparing blocks aged up to 11 years, 69 had been treated and 14 have had no wound protection applied. Details regarding the type and extent of wound protection applied were not collected for this survey.

Blocks varied greatly for both dieback and foliar symptom incidence, and logarithmic and linear regressions provided the greatest coefficients of determination, respectively (Figure 13). Overall, blocks with wound protection had slightly lower incidence of dieback and foliar symptoms (R^2=0.34-0.50). For vines aged between 5 and 12 years, 14 blocks that had wound protection applied were recorded with 20-80% dieback incidence. These blocks also had up to 16% incidence of eutypa foliar symptoms.



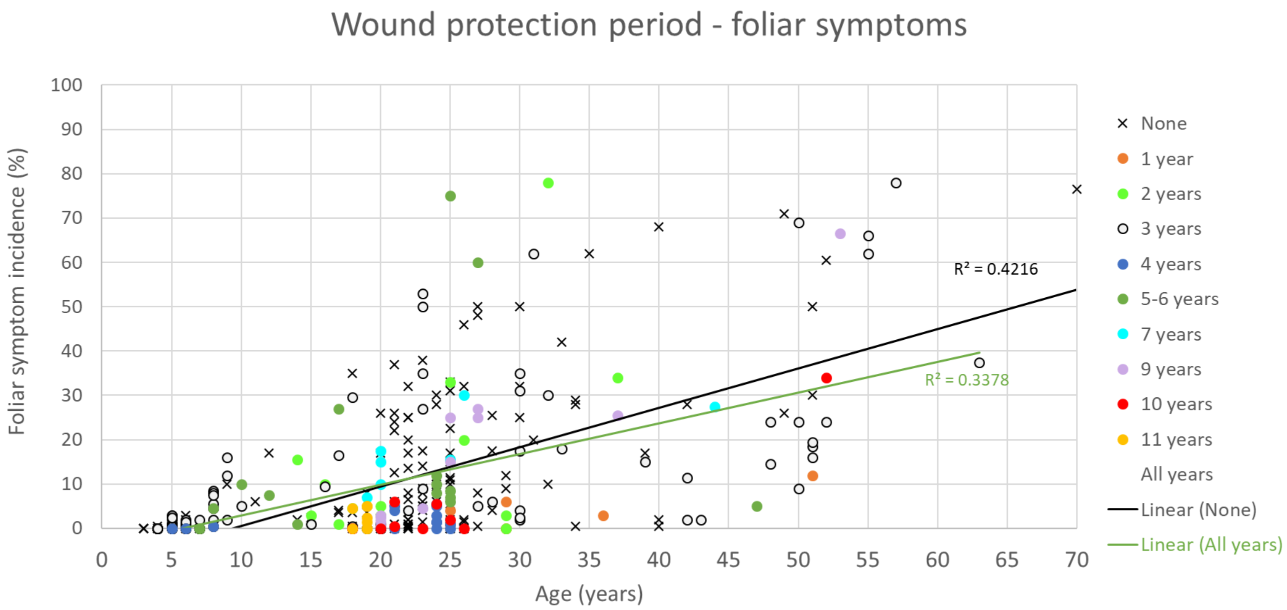


Figure 13. Scatter plots showing the incidence of dieback and foliar symptoms of eutypa dieback with vine age. Blocks where wound protection has not been applied are marked with an X and blocks that have been regularly treated with wound protection following pruning are indicated by dots, with colours denoting the number of years since wound protection commenced. The orange box shows the cluster of blocks aged between 5 and 12 years, which have been treated with wound protection and had high incidence of dieback. Logarithmic and linear regressions provided the greatest coefficients of determination for dieback and foliar symptom incidence, respectively.

Figure 14 shows an enlarged scatter plot with blue horizontal bars extending back in time to show the years that wound protection was applied for selected blocks. The red shape highlights the number of years that wound protection was not applied, and hence were exposed to infection by pathogen spores. As the incidence increased, so too did the number of years of exposure.

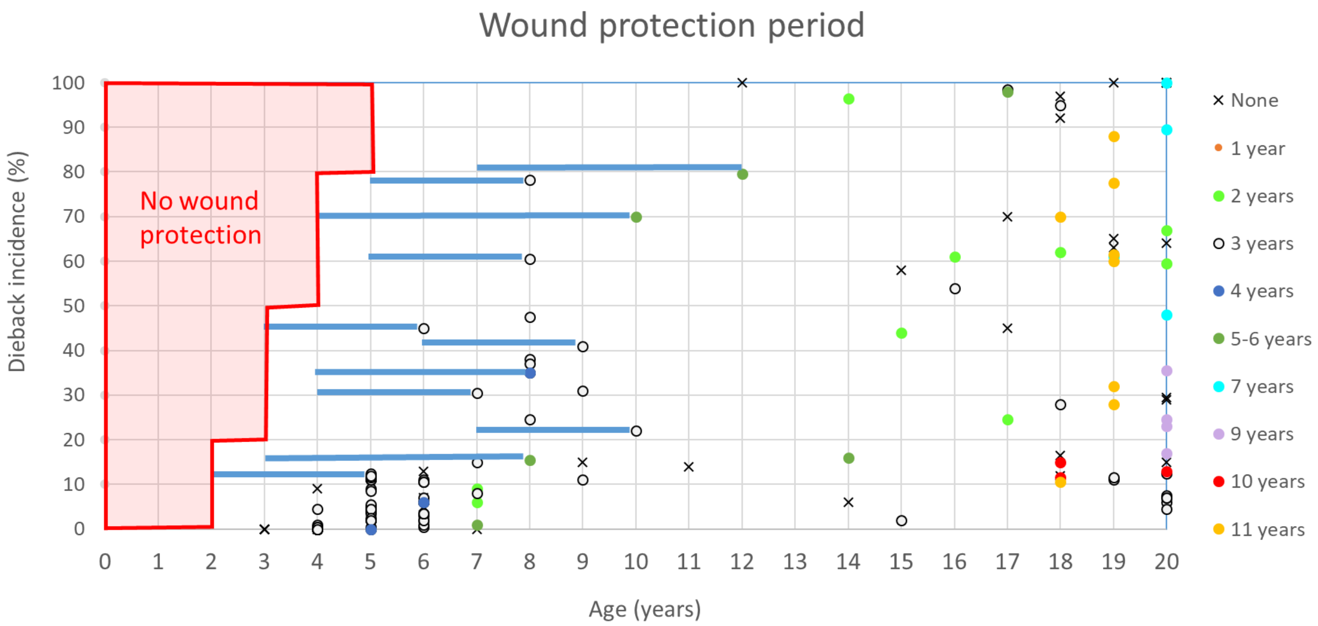


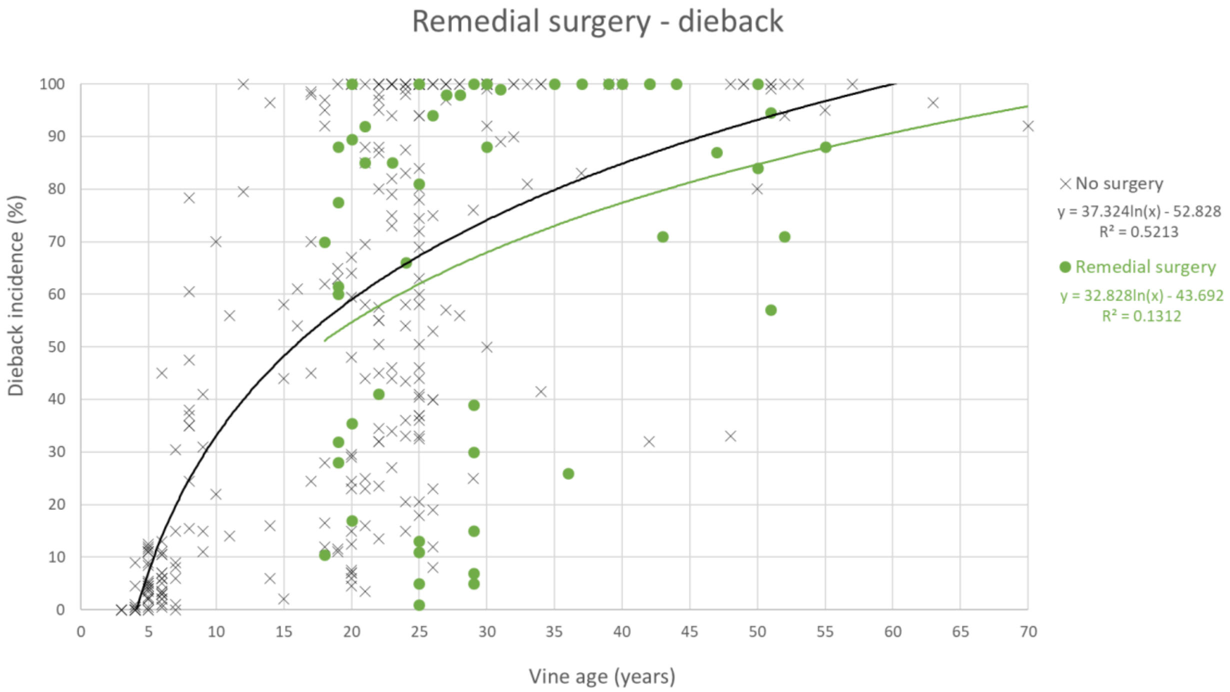
Figure 14. Scatter plot showing the incidence of dieback with vine age. Blocks where wound protection has not been applied are marked with an X and blocks that have been regularly treated with wound protection following pruning are indicated by dots, with colours denoting the number of years since wound protection commenced. The blue horizontal bars indicate the years of protection prior to the survey and the red shape highlights the period that pruning wounds were not protected.

Pruning wound protection sprays were applied to 10 blocks from the first year of pruning, and vines were 4 or 5 years old at the time of the survey. Of these, six blocks had no disease and the other four were recorded with up to 4.5% incidence of dieback (overall average of 1.9%). When compared with the 25 blocks that were 4 or 5 years old and wound protection was applied from the second year after planting, only two were recorded with no dieback, and 23 blocks were recorded with up to 12.5% incidence of dieback (overall average of 5.4%). Furthermore, no foliar symptoms were recorded in blocks that had wound protection from the first year, whereas 15 of the 25 blocks protected from second year were recorded with up to 3% incidence of foliar symptoms.

Remedial surgery

Of the blocks surveyed where remedial surgery information was available, 56 blocks were remediated, 278 were not. Of the remediated blocks, 19 were reworked in the previous 7 years, since the previous survey in 2012, and a further 33 blocks were reworked 8-28 years prior to the 2019 survey.

Blocks varied greatly for both dieback and foliar symptom incidence, and logarithmic and linear regressions provided the greatest coefficients of determination, respectively (Figure 15). Overall, there was only a small reduction in dieback and foliar symptom incidence for blocks that have been remediated (R^2=0.13 and 0.26, respectively) compared with blocks that had not (R^2=0.52 and 0.39, respectively).



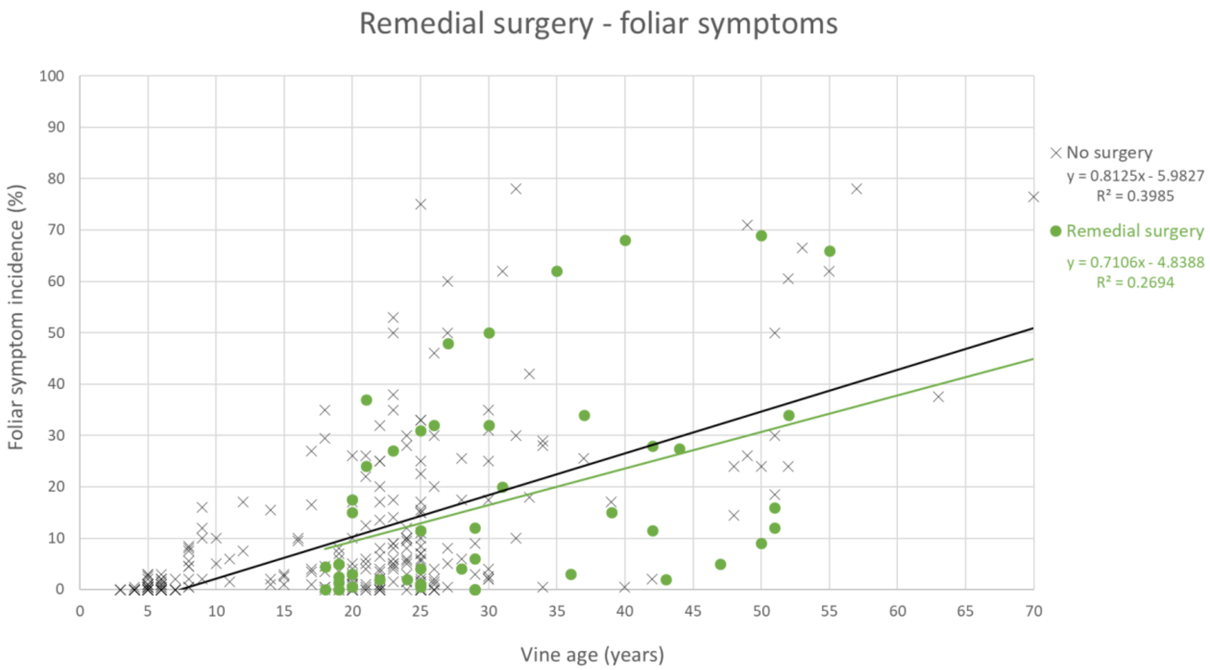


Figure 15. Scatter plots showing the incidence of dieback and foliar symptoms of eutypa dieback with vine age. Blocks where remedial surgery has never been undertaken are marked with an X and blocks that have been subjected to remedial surgery are indicated by green dots. Logarithmic and linear regressions provided the greatest coefficients of determination for dieback and foliar symptom incidence, respectively.

A subset of blocks which have been remediated in the past 11 years, and followed with routine pruning wound protection ever since, are shown in Figure 16. It reveals varying levels of dieback incidence in remediated blocks, with particularly high incidence (60-90%) in five blocks that were 18-19 years old which had been remediated 11 years earlier. Details on height of cuts or incidence of trunks remaining with visible infection after surgery were not available.

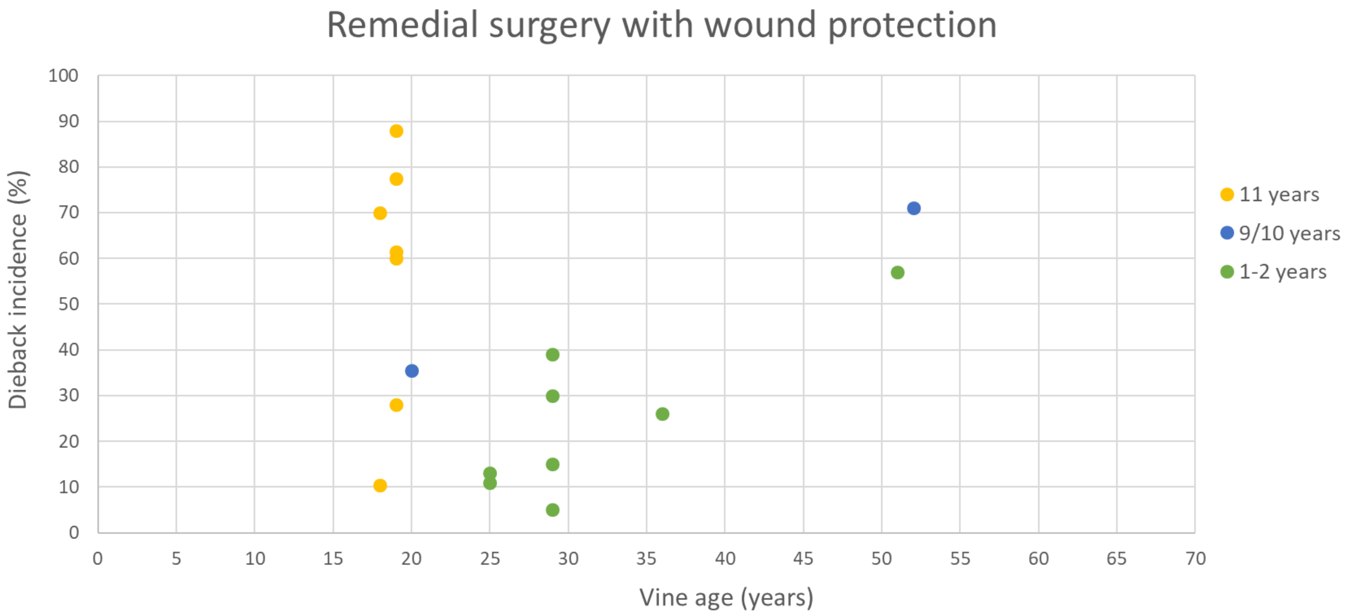


Figure 16. Scatter plot showing the incidence of dieback with vine age on a subset of blocks which have been remediated and then immediately followed up with regular wound protection since remediation. Coloured dots represent years since remedial surgery undertaken.

Frost protection

Of the blocks surveyed where frost protection information was available, 126 blocks had frost protection and 204 did not. Of the frost-protected blocks where details were supplied, 47 had fans and 67 had sprinklers.

Blocks varied greatly for both dieback and foliar symptom incidence, and logarithmic and linear regressions provided the greatest coefficients of determination, respectively (Figure 17). There was little difference in dieback and foliar symptom incidence between blocks with frost protection and without. Dieback incidence was slightly greater for blocks with sprinklers (R^2=0.79) compared to blocks with fans (R^2=0.22) for frost protection.

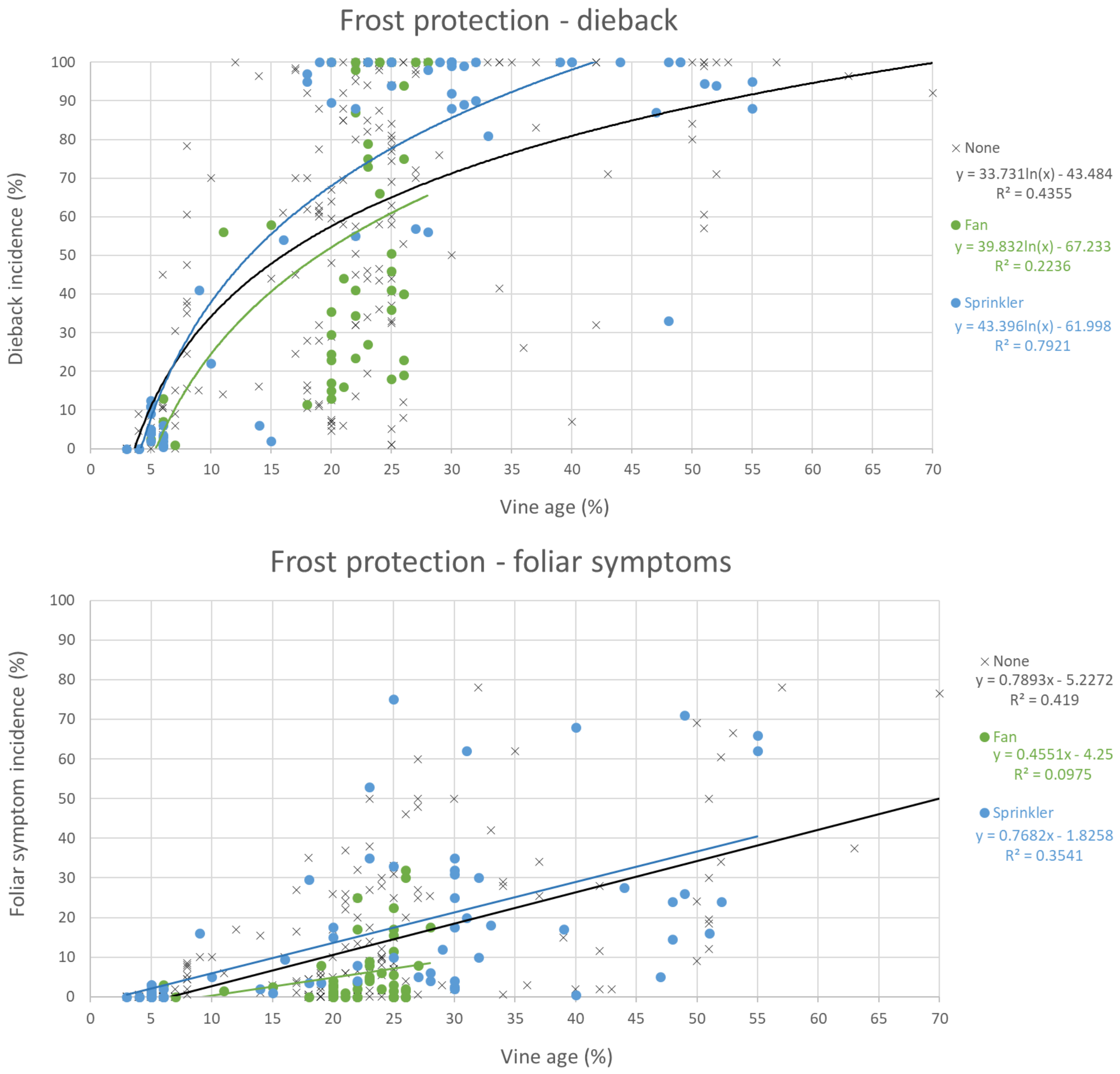


Figure 17. Scatter plots showing the incidence of dieback and foliar symptoms of eutypa dieback with vine age. Blocks with no frost protection are marked with an X and blocks that have frost protection are indicated by dots, with green denoting blocks with fans and blue denoting blocks with sprinklers. Logarithmic and linear regressions provided the greatest coefficients of determination for dieback and foliar symptom incidence, respectively.

Conclusions

The overall mean incidence of dieback and foliar symptoms in the Limestone coast survey was 52 and 11%, respectively. For Coonawarra and Wrattonbully alone, the incidence has increased from 41 and 8% in 2012, to 58 and 14% in 2019, respectively. This represents a substantial increase in incidence of dieback and foliar symptoms of 17 and 6%, respectively, over the past 7 years.

Sub-region

In 2019, the average vine age of all blocks surveyed in each of the three sub-regions was similar (21-23 years), which allowed a relative comparison between them. Overall incidence of dieback was greatest in Wrattonbully (64%), followed by Coonawarra (57%) and Mt Benson/Robe (34%). In terms of foliar symptoms of eutypa dieback, Coonawarra had the greatest incidence (16%), compared with Wrattonbully (7.5%) and Mt Benson/Robe (1.2%). Coonawarra and Wrattonbully are older and larger regions than Mt Benson/Robe, which are also isolated and subject to prevailing winds from the ocean to the south. These factors reduce the exposure of Mt Benson/Robe vineyards to fungal spore inoculum post-pruning and may have contributed to the lower levels of disease observed in this sub-region.

In Coonawarra, there has been an increase in incidence of dieback of around 1% per year over the 7 years between the two surveys. In Wrattonbully, there has been a much greater rate of increase in incidence of dieback of 7.5% per year. One reason for this may be the lack of vineyard rejuvenation through remedial surgery and replanting in Wrattonbully compared with Coonawarra. This rate of increase is alarming and serves as a warning for growers in Wrattonbully to put more emphasis on managing trunk disease. In Mt Benson/Robe, eutypa dieback is poised to present a major problem in the future, and if not managed, may lead to similar incidences of dieback as its neighbouring sub-regions.

Vine age

Eutypa dieback foliar symptoms were observed in a Cabernet Sauvignon vine 4 years of age, the youngest recorded with foliar symptoms in Australia. The youngest vines previously observed with foliar symptoms were 5 years of age, in the 2012 Limestone Coast survey, and foliar symptoms were reported on 7-year-old vines in the Adelaide Hills (Loschiavo *et al.* 2007). It takes 3 to 8 years for foliar symptoms to develop after infection has occurred (Sosnowski *et al.* 2007a), so it is likely that these young vines were infected in the first few years of production, highlighting the importance of wound protection from planting.

Dieback symptoms were reported at greater incidences than foliar symptoms. The youngest vines observed with dieback were 4 years old, with five blocks having up to 9% incidence. In 2012, 5-year-old vines were the youngest recorded with dieback. As vines age, symptoms become more severe due to; longer time for disease to establish and express symptoms, greater number of wound sites for infection and exposure to more pruning events and stress. The incidence of blocks in Limestone Coast with 100% dieback was 5% in 2012 and has increased to 20% in 2019.

Variety

Cabernet Sauvignon and Shiraz, which represent the majority of plantings in the Limestone Coast, had the highest incidence of dieback and eutypa foliar symptoms. Merlot and Chardonnay were recorded with the lowest incidence of dieback and foliar symptoms in the survey. Sauvignon Blanc, although only represented by 11 blocks in this survey, had a higher rate of increase in dieback than the four previously mentioned varieties. These results support previous research on susceptibility of varieties (Sosnowski *et al.* 2007b) and the results from surveys in other wine regions in Australia (Wicks 1975, Highet and Wicks 1998, Loschiavo *et al.* 2007, Sosnowski *et al* 2010) and New Zealand (Sosnowski and Mundy 2019).

Rootstocks and clones

Although blocks varied greatly for both dieback and foliar symptom incidence, vines planted on rootstocks 101-14 and Teleki 5C had the lowest dieback and foliar symptom incidence, and vines planted on 110 Richter had the greatest incidence, compared with all other rootstock and own-rooted blocks. However, these results should be taken with caution, due to low sample numbers and young age of vines on many of the rootstocks, leading to low coefficients of determination.

When considering clones of Cabernet Sauvignon in this survey, there was little evidence of any difference in incidence of dieback or foliar symptoms. When focussing on the clone SA125, there was some clustering of blocks on the same rootstocks, which may suggest an interaction between clones and rootstocks. Based on the limited representative sample size from the survey, this requires further investigation.

With Shiraz clones, BVRC12 had greater incidence of dieback than all other clones, which were similar to each other. Incidence of foliar symptoms did not reveal any substantial differences.

Current Wine Australia funded research at SARDI is evaluating rootstock and scion combinations for dieback incidence in historical trials. These results will inform further scientific evaluation of the susceptibility of clonal scion material, and the effect of different rootstocks, to colonisation by eutypa and botryosphaeria dieback pathogens.

Pruning management

Blocks varied greatly for both dieback and foliar symptom incidence and there were no differences between the three spur pruning management styles: detailed, semi-detailed and hedged, for dieback or foliar symptoms of eutypa dieback. Cane-pruned blocks had lower incidences of dieback and foliar symptoms than spur-pruned blocks, however, due to the low number of representative samples, coefficient of determination was low and, therefore, results were inconclusive.

These results are not consistent with the understanding that machine hedge pruning results in large wounds on the cordons and trunks when saws are used, increasing the likelihood of infection compared with spur pruning by hand. It may be that other factors are confounding the results in this survey, such as variety, clone and rootstock combinations, and remedial surgery and pruning wound protection strategies. Furthermore, hedge-pruned vines may disguise dieback, as new shoots fill any gaps, possibly leading to an underestimation of disease incidence.

Despite the pruning management system, these results highlight the importance of managing trunk disease in the vineyard.

Wound protection

Overall, blocks with wound protection had only slightly lower incidence of dieback and foliar symptoms than those with no wound protection. Commencing wound protection on mature vines that are already infected with eutypa dieback is unlikely to have any impact on the progression of disease. However, an alarming result from the survey was the 14 blocks (aged 5-12 years), each reported to have a routine post-pruning wound protection program, that were recorded with 20-80% dieback incidence. When considering the number of years that wounds had been protected in each block, it was revealed that vines were exposed to infection for the first 2-5 years of production. Furthermore, when comparing the 10 blocks that had wound protection applied from first year of planting (aged 4 or 5 years) with the 25 blocks that wound protection commenced from the second year of pruning or later, it was evident that considerable infection must have occurred in the first pruning season. Spore trapping in the Coonawarra region has revealed the regular presence of eutypa and botryosphaeria dieback pathogens throughout the pruning season every year (Billones-Baaijens *et al*. 2017), so it is likely these vineyards were infected in the first year of pruning. Current recommendations are to protect wounds from the first pruning following planting, and these observations support this advice. Also, efficacy of wound protectants rely on good coverage of wounds, so it is important to adjust spray machinery and check wound coverage (Ayres *et al.* 2017). It has also been shown that spores may be present during spring and summer rain events, which may lead to infection of wounds made during summer shoot thinning. This possibility will be addressed as part of Wine Australia research in the next few years. Future surveys should focus on monitoring blocks with management strategies in place from planting compared with those with delayed implementation, or none at all.

Reworking

Previous research has shown that reworking or remedial surgery on mature, infected vines is the most effective means of controlling the disease (Sosnowski *et al.* 2011). In this survey, blocks varied greatly for both dieback and foliar symptom incidence and, overall, there was only a small reduction in incidence for blocks that have been remediated. The particularly high incidence in some remediated blocks, that were followed with routine wound protection, may be because not all infection was removed. It is recommended that all visible signs of infection are removed, along with a further 10 cm of clean wood, as the pathogens can grow ahead of the stained wood (Sosnowski *et al*. 2007b). For this survey, details on height of cuts or incidence of trunks remaining with visible infection after surgery were not available.

Frost protection

Blocks varied greatly for both dieback and foliar symptom incidence and there was little difference between blocks with frost protection and without. Dieback incidence was slightly greater for blocks with sprinklers compared to blocks with fans. Although extra wetting of vines from sprinklers could exacerbate spore release, frost protection is only undertaken during early spring growth, when pruning is not usually conducted.

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