A Revised Management Program for Grapevine Black Spot

Final Report - December, 1992

DAV 5GW

EXECUTIVE SUMMARY

In the late 1980's the future of dithiocarbamate fungicides in agriculture was in doubt because of concerns related to toxicology. The threatened withdrawal of dithiocarbamate fungicides such as ziram, thiram, mancozeb and metiram would have left grapegrowers without suitable fungicides for control of black spot. Prior to the early 1950's, black spot was a major disease problem on susceptible grape varieties, including Sultana, the predominant drying variety. Since the introduction of the dithiocarbamate fungicides, the disease has been effectively controlled and is rarely seen in commercial vineyards.

In July 1989 the Dried Fruits Research and Development Council and the Grape and Wine Research and Development Corporation jointly funded a three year project on black spot. The aims of the project were to identify fungicides that were potential replacements for the dithiocarbamate fungicides, to study disease biology and to develop new management programs for black spot that do not rely on the use of dithiocarbamate fungicides.

Evaluation of alternative fungicide

Four fungicides were identified as suitable alternatives to the dithiocarbamate fungicides in black spot control programs. One product is registered for use on grapevines, another is in the registration process, while the other two are possible candidates for future registration. The majority of fungicides registered for the control of other grapevine diseases do not control black spot.

Studies of black spot spread

Spread of black spot is slow by comparison with other grapevine diseases such as downy and powdery mildew. In inland Australia, incidence of disease is low or the disease is absent from most commercial vineyards. Favourable seasons for disease spread occur infrequently. Even when conditions are highly favourable for disease spread, early season crop loss is mostly restricted to vines with the disease in previous seasons.

Management of black spot

In inland Australia an annual fungicide spray program for the control of black spot is not required unless the disease is present in a vineyard. Spray need can be predicted from weather data and development of a computerised simulator to assist grapegrowers in spray decision making is in progress. The simulator is being integrated into a software program for management of a range of vineyard pests and diseases.

Since the commencement of the project, the short term future of some dithiocarbamate fungicides such as mancozeb has been assured following a comprehensive revision of their toxicological data packages by the chemical industry. Results of research on black spot management and biology have been communicated to the industry through a variety of media and are being published in scientific journals.

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A REVISED MANAGEMENT PROGRAM FOR GRAPEVINE BLACK SPOT

FINAL REPORT (DECEMBER, 1992)

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1. Preface

This report covers research conducted between July 1989 and June 1992 on grapevine black spot or anthracnose funded by the Australian Dried Fruits Research and Development Council (Project 43F) and the Australian Grape and Wine Research and Development Corporation (Project 5V).

2. Introduction

Black spot or anthracnose *(Elsinoe ampelina)* can cause serious crop loss on susceptible grape varieties in years with high spring rainfall. However, since the introduction of the dithiocarbamate fungicides, crop losses from the disease have been rare. The low frequency of seasons favourable for disease epidemics combined with the routine use of very effective fungicides (e.g. ziram) have resulted in the absence of the disease from most vineyards in most seasons in inland Australia.

Nevertheless, doubt about the long term future of fungicides, in particular the dithiocarbamate fungicides, is placing pressure on the grape industry to not only reduce the use of these fungicides but to also look for alternative methods of control. In response to this, the Dried Fruits Research and Development Council (DFRDC) and the Grape and Wine Research and Development Corporation (GWRDC) jointly funded research on the disease.

The principal aims of this research were as follows:-

(1) To evaluate fungicides for the control of grapevine black spot as potential

replacements for ziram,

(2) To study the biology of black spot, and

(3) To integrate these aspects and develop a management strategy that does not entirely rely on the use of dithiocarbamate fungicides.

3. Evaluation of alternative fungicides to the dithiocarbamates

Australian grapegrowers currently use a range of different fungicides in disease management programs. Apart from the dithiocarbamates (e.g. mancozeb, metiram, thiram, zineb, ziram), other major groups of fungicides used include the benzimidazoles (e.g. benomyl, carbendazim, thiophanate-methyl), copper-based fungicides (e.g. copper oxychloride, cupric hydroxide), the demethylation inhibitors or the DMI fungicides (e.g. fenarimol, propiconazole, triadimefon, triadimenol), the dicarboximides (e.g. iprodione, procymidone, vinclozolin), the phenylamides (e.g. mixtures with benalaxyl, metalaxyl or oxadixyl), the phthalonitriles (e.g. chlorothalonil) and sulphur fungicides (e.g. wettable sulphur).

During fungicide evaluations to find suitable alternatives to ziram for black spot control, fungicide candidates for screening tests were selected from the range of fungicides already used by grapegrowers for the control of other diseases. Newly developed fungicides with potential efficacy against black spot were also included. The ultimate aim of the screening tests was to produce field efficacy and residue data on fungicides with the most potential to replace ziram in black spot control programs.

Over 25 fungicides were screened in laboratory and glasshouse tests. The results of these tests combined with information from reports in the literature are summarised in Table 1. For more detailed reports on individual screening tests see Appendix 1.

As a result of glasshouse screening tests, six fungicides were selected for further comparison with ziram under field conditions. These fungicides were chlorothalonil, dichlofluanid, fluazinam, captan, prochloraz and fenarimol. The field test was conducted on infected Sultana grapevines at the Department of Agriculture's Mid Area property where overhead misters were used to promote disease spread. The results of this trial were in line with the results of previous glasshouse efficacy tests. Four fungicides, chlorothalonil, dichlofluanid, fluazinam and captan, had similar efficacy against black spot to that of ziram.

Residue data from another field test were collected for the fungicides ziram, captan, dichlofluanid and fluazinam. Sprays of these fungicides were applied from bud-burst to the 30cm shoot stage and from bud-burst to flowering in 3-spray and 5-spray programs respectively. Fungicide residues were not detected in fruit at

harvest when spraying ceased at the 40cm shoot stage. However, the 5-spray program from bud-burst to flowering resulted in detectable residues in 2 out of 4 fungicide treatments (Appendix 2).

Table 1. Summary of results of fungicide testing programs conducted at the Sunraysia Horticultural Research Centre, Irymple combined with reports of fungicide performance in the literature.

Fungicide or Fungicide Class	Result
dithiocarbamates	Excellent to Good
captan	Excellent to Good
dichlofluanid	Excellent
fluazinam	Excellent
chlorothalonil	Good[P]
sterol inhibitors	Good to Poor[P]
copper	Poor
benzimidazoles	Poor
sulphur	Poor
lime sulphur	Poor
dicarboximides	Poor
potassium phosphite	Poor
phenylamides	Poor

Excellent - provides excellent control.
Good - provides good control.
Poor - has little or no controlling effect.
P - potential problem associated with phytotoxicity during early season use particularly on Sultana

4. Studies of disease biology

The biology of black spot was studied with a view to increasing understanding of disease development in Australian vineyards and using this information as a basis for improving the efficiency of disease management programs.

Previously documented studies of anthracnose (e.g. Brook, 1973; Mirica, 1988) were reviewed (Appendix 3) and where required, further studies were undertaken at the Sunraysia Horticultural Centre, Irymple to clarify important aspects of disease biology.

4.1 Spread of black spot (*Elsinoe ampelina*)

Spread of black spot is slow in comparison with other major diseases of grapevines. This is partly due to the limited mobility of the asexual spores of *Elsinoe ampelina*, but also the absence of the disease from the majority of vineyards.

Table 2. Comparative risk of damaging spread of three grapevine diseases in inland Australia.

Disease	Critical risk period for crop loss (days)	Days required for destructive spread[i]	Frequency of favourable seasons
downy mildew	40cm to berry softening (8)	15[ii]	10-20%
powdery mildew	Bud burst to berry softening (12)	60[iii]	90-100%
black spot	Bud burst to berry set (80)	70[iv]	5-10%

i. Based on favourable seasonal conditions
ii. A single secondary infection period at flowering can cause 100% crop loss.
iii. Spread of powdery mildew from flagshoots (0.01% of buds) to neighbouring vines can occur in 40 days, and bunch damage can occur in 60 days.
iv. Based on overwintering inoculum levels of 0-2 cankers per infected vine.

From budburst until mid-season, significant crop loss is only likely to occur on or in the vicinity of vines that have overwintering cankers at the start of the season, even in seasons that are highly favourable for disease and in vineyards where an early season spray program is not applied (Appendix 4). After flowering, black spot can spread rapidly throughout the vineyard, but because of the seasonal decline in bunch and leaf susceptibility (Appendix 3), extensive crop damage remains confined to localised areas with the disease in the previous season. Substantial crop loss is likely only after a series of seasons with wet springs when overwintering inoculum persists on a larger number of vines per vineyard, especially when early season control programs have not been applied.

Progress has been made towards producing a computerised biological model or simulator of black spot development in vineyards that takes into account current knowledge of the disease. The model is comprised of several sub modules that simulate the individual facets of disease development. These include an infection

model that predicts infection periods based on calculations made from weather data. A second module predicts when symptoms will first appear in the vineyard. The model uses these calculators in conjunction with the growth stage of the vine to predict the likely rate of disease increase in the vineyard and the need for control. Vineyard studies of the spread of black spot on which the model is based are presented in Appendix 4.

Cultivar susceptibility is also an important component of the model and is based on grower experience and recent studies (Appendix 5).

This model is a basic component of a 'black spot' module that will be part of the AusVit expert system for Australian viticulture (Appendix 7). AusVit is a computer driven decision aid device that can run on an IBM compatible personal computer with at least 640K RAM. Development of the system is expected to take 3-4 years, including a phase of validation of the biological information and system construction.

5. Black spot management options

5.1 Routine spraying

Black spot can be controlled by applying a suitable protectant fungicide every 10 to 14 days from 50% budburst until fruit set, regardless of weather conditions and disease presence in vineyards. Up to 5 sprays may be required. This strategy is most appropriate when disease pressure is high (e.g. when there is overwintering inoculum in a vineyard and/or susceptible cultivars are exposed to frequent spring rainfall).

5.2 Strategic spraying

In inland Australian vineyards where black spot is absent, an annual control program is not required. The need for spraying can be estimated from the number of infection periods that have occurred in the season and is a component of the AusVit black spot module. Spread, even from heavily infected vines, can not occur in the absence of suitable conditions. After a season in which there was no infection or very few infection periods, the potential for disease carry-over will be low and there will be little need for control measures. The pruning of well established vines will remove most infected material providing standard spur pruning or cane pruning techniques are applied. When several infection periods occur in a season, there will be greater opportunity for disease spread and the inclusion of a fungicide for black spot control with other sprays up to berry set is appropriate. Alternatively the vineyard could be checked regularly for disease symptoms. If black spot is discovered, sprays should be applied up

to berry set each season for up to 3-5 consecutive years until sources of disease inoculum are eliminated.

An article summarising management options for black spot is presented in Appendix 6.

6. Communication to industry

Extension of black spot management information is part of an overall Departmental advisory effort on disease and pest management. This includes the packing shed newsletter Cropwatch and the dial-up recorded information service Horticulture Hotline. The Cropwatch newsletter is received by approximately two-thirds of growers in the Sunraysia district. During the spring of 1992 Hotline patronage peaked at over 150 calls per week. In October 1992 a disease and pest field day was held at the Sunraysia Horticultural Centre and attended by 150 growers. The aim of the day was to help growers recognise early symptoms of grapevine diseases, including black spot.

A two minute video production on management of black spot was produced at the Sunraysia Horticultural Centre video unit and screened on the "On the Land" television slot. In 1992 a jingle was used to promote understanding of conditions required for downy mildew infection and a composition has also been prepared for black spot. Talks on management of black spot have also been presented to grower and chemical reseller groups.

7. Further Research

The suppliers of chlorothalonil, dichlofluanid and fluazinam will be encouraged to register these fungicides for use against black spot. Where appropriate, further field tests may be conducted with the help of chemical companies to ensure that there are sufficient data for registration applications.

The black spot management options outlined in Section 5 will be tested further in the DFRDC project " Reduced use of chemicals in dried vine fruit production" and to some extent in the GWRDC project 7V "Strategic management of grapevine powdery mildew". In these projects both strategic and routine spraying practices will be evaluated in commercial vineyards.

Further improvement and validation of the computerised simulator of black spot is planned during evaluations of the AusVit expert system over the next three years.

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Appendix 1 Evaluation of fungicides against anthracnose

a) Evaluation of control of grapevine anthracnose (*Elsinoe ampelina*) by pre-infection fungicides.

R.D. Magarey, R.W. Emmett and P.A. Magarey

Manuscript of a paper to be published in
Australasian Plant Pathology 22:xx-x (1993).

b) Evaluation of fungicides for control of anthracnose on grapes, 1990.

B.E. Coffey, R.W. Emmett and R.D. Magarey

Paper published in *Fungicide & Nematicide Test* 46:83 (1991)

c) Evaluation of fungicides for control of anthracnose on grapes, 1991.

R.D. Magarey and R.W. Emmett

Paper published in *Fungicide & Nematicide Test* 47:63 (1992)

d) Evaluation of demethylation inhibiting (DMI) fungicides for control of anthracnose on grapes, 1991.

R.D. Magarey and R.W. Emmett

Paper published in *Fungicide & Nematicide Test* 47:62 (1992)

Evaluation of control of grapevine anthracnose (*Elsinoe ampelina*) by pre-infection fungicides.

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Abstract

Four pre-infection fungicides were found to be as effective as the industry standard ziram for the control of grapevine anthracnose. In field and glasshouse trials dichlofluanid, captan, fluazinam and chlorothalonil all provided excellent disease control. Prochloraz and fenarimol were less effective, but still provided some control. Fenarimol, chlorothalonil and prochloraz displayed varying degrees of phytotoxicity associated with early season use. In general the demethylation inhibiting fungicides have little potential for control of grapevine anthracnose.

Introduction

Grapevine anthracnose (black spot) caused by *Elsinoe ampelina* (Shear 1929) is historically an important disease of grapes (*Vitis vinifera L.*) in Australia. Past outbreaks of the disease have caused serious crop losses in Sunraysia, the Riverland and the Murrumbidgee Irrigation Area (MIA) as well as other regions. However the introduction of dithiocarbamate fungicides such as ziram and thiram in the 1950's (Coombe 1953; Taylor 1954) has resulted in a decline in the severity and occurrence of black spot.

The possible withdrawal of the dithiocarbamate fungicides for toxicological reasons (Emmett 1990) creates the need for replacement fungicides for disease control. Many of the fungicides registered for control of other diseases on grapevines are ineffective for control of anthracnose; e.g. sulphur, benzimidazoles (Coffey *et al.* 1991), copper (Emmett *et al.* 1981) vinclozolin and procymidone (Coffey *et al.* 1991, Magarey and Emmett 1992b), lime sulphur (Moore pers. comm.) and metalaxyl (Moore and Schroeder 1983). Other fungicides have been shown to be effective against anthracnose; captan/captafol (Emmett *et al.* 1981) chlorothalonil (Magarey *et al.* 1977) and prochloraz and fenarimol (Coffey *et al.* 1991). This paper reports on *in vitro*, glasshouse and field testing of fungicides for control of grapevine anthracnose. Other glasshouse tests have been completed as part of this project but have been reported elsewhere (Coffey *et al.* 1991; Magarey and Emmett 1992a; Magarey and Emmett 1992b).

Methods

Inoculum Conidia of *E. ampelina* were obtained from 14-30 day old lesions on leaves of potted glasshouse grapevines previously inoculated with a mixture of isolates from Victoria and South Australia.

Plants Potted grapevines *V. vinifera* cv Sultana were used in both glasshouse and *in vitro* tests.

***In vitro* tests** (Experiment 1) Nine fungicides (Table 1) were applied to single vine plots arranged in a randomised block design and replicated six times. Each treatment was applied by spraying the five terminal leaves on one shoot per vine to runoff. Twenty four hours later 18 young leaves per treatment were harvested. For each treatment 100 leaf discs (9mm) were cut from the sprayed leaves and placed in ten petridishes (9cm) containing water agar. Control discs were cut from untreated leaves. Discs were then inoculated with a 10 µl drop of conidial suspension of *E. ampelina*. Two inoculum levels were used ($1x10^5$ and $5x10^3$ conidia per ml) with discs from 5 dishes being inoculated for each level and treatment combination. After five days the number of discs developing lesions of *E. ampelina* were counted. Untreated and uninoculated discs did not develop lesions. Data were expressed as the percentage of discs infected and analysed statistically by regression.

Glasshouse tests (Experiment 2 and 3) Fungicides were applied to single vine plots arranged in a randomised block design and replicated six times. The fungicides were tested against ziram as the standard treatment and are listed in Table 1. Each treatment was applied once to one young vine shoot per plot by spraying to runoff. After 24 h all treated vines and untreated controls were sprayed with a suspension of $4x10^4$ *E. ampelina* conidia /ml and immediately enclosed in a polyethylene bag for 24 h. The plants remained in the glasshouse for the duration of the experiment. The glasshouse was under drip irrigation and anthracnose leisons did not develop on uninoculated untreated plants.

Disease severity was assessed on the five terminal leaves and internodes of each shoot 14 days after treatment. Disease severity on leaves was rated with the aid of a diagrammatic key containing 11 categories of % area of leaf infected. The following were defined as upper limits: 0%, 0.4%, 0.8%, 1.6%, 3.0%, 6.3%, 12.5%, 25%, 50%, 75% and 100%. Disease severity on stems was assessed with the aid of a diagrammatic key containing 8 categories for % area of internode infected. The following were defined as upper limits: 0%, 0.6%, 1.2%, 2.4%, 4.8%, 9.6%, 19.2%, 38.4%. The percentage score for each of the 5 leaves and 5 internodes per shoot was summed and analysed by ANOVA following a log transformation. In experiment 2 disease severity on stems was not assesed. The incidence of *E. ampelina* on leaves and stems was analysed by regression and treatment means were compared by pairwise LSD.

Field Trial (Experiment 4). Seven fungicides were applied by handline sprayer to two vine plots in a *V. vinifera* cv Sultana vineyard near Mildura, Victoria. All treated vines had overwintering inoculum present as shoot cankers, inoculated artificially in the previous spring. The experimental design was a randomised incomplete block design with treatments replicated seven times. The treatments were applied four times; September 13 (12 days after bud burst), September 24, October 9 and 22 1991. Two to three days after treatment disease spread was promoted by artificially misting with overhead misters. Disease assessment was made on 25 shoots per vine. Disease severity on the leaves and stems of the first six nodes of each shoot were assessed on November 11 and 20 using the same procedure useed in the glasshouse. The total score for 50 shoots per plot was summed and analysed by ANOVA following a log-transformation.

On December 16 phytotoxicity on twenty shoots per plot was assessed for fenarimol, prochloraz and chlorothalonil. Five treated plots were selected at random. With the aid of

a diagrammatic key for % leaf area necrotic a scale of 0-4 (Doster and Sall 1984) was used to score the youngest six leaves on each shoot. The total score for each plot was summmed and analysed by ANOVA.

Results

In vitro (Experiment 1) There was no significant difference ($P > 0.05$) between the incidence of *E. ampelina* from either inoculum concentration, so the results are expressed as a single mean score. Ziram provided complete control of anthracnose on leaf discs where as chlorothalonil, prochloraz and flusilazole provided fair control (Table 2). Although mycobutanil and difenoconazole also significantly ($P < 0.05$) reduced infection compared to the untreated control, propiconazole and hexaconazole did not.

Glasshouse (Experiment 2) All fungicides significantly reduced disease incidence and severity compared to that of the control (Table 3).

Glasshouse (Experiment 3) Ziram was more effective than any other fungicide. Ziram, prochloraz and tebuconazole significantly ($P < 0.05$) reduced % leaf area infected but only ziram significantly reduced % stem area infected (Table 4). Propiconazole, penconazole and triflumizole were ineffective. No phytotoxicity was observed in this trial.

Field Trial (Experiment 4)

Fungicide Efficacy Levels of disease severity in untreated controls was low, but all fungicides significantly ($P < 0.05$) reduced both % leaf and % stem area infected (Table 5). Chlorothalonil, dichlofluanid, captan and fluazinam were as effective as the standard treatment ziram in reducing stem and leaf disease. Prochloraz was significantly ($P < 0.05$) less effective than ziram in % leaf area infected, whilst fenarimol was the least effective treatment.

Phytotoxicity Chlorothalonil, prochloraz and fenarimol were phytotoxic and induced interveinal necrosis, curving down of the leaf edge and leaf thickening. Phytotoxicity was confined to the first six leaves on each shoot and the first two leaves were the worst effected (Table 6). Fenarimol was the only treatment to be significantly more phytotoxic than the control. Phytotoxicity was most severe from sprays applied in September. No phytotoxicity was observed in the other four treatments.

Discussion

Our experiments showed that ziram, dichlofluanid, captan, chlorothalonil and fluazinam were very effective as pre-infection fungicides for control of grapevine anthracnose. Efficacy of these fungicides in the field was established under low disease pressure, but excellent control was also obtained in the glasshouse under conditions of high disease severity. In most commercial vineyards the incidence of disease is extremely low, however it may increase if early season control is neglected for one or more seasons with favourable conditions for disease spread. As a consequence many vineyard managers apply routine early season treatments regardless of disease incidence.

Nearly all the demethylation inhibiting (DMI) fungicides gave poor control of the disease. Many DMI fungicides were also phytotoxic in glasshouse screening tests (Magarey and Emmett 1992a). The cultivar Sultana is highly sensitive to DMI damage compared to some other cultivars and damage is more severe the earlier in the season these compounds are applied (Doster and Sall 1984). The necessity for anthracnose spray schedules to begin at budburst (Coombe 1954) makes phytotoxicity an important consideration and probably precludes the use of some DMI fungicides for the control of *E. ampelina* in Australia.

Ziram, other dithiocarbamates and dithianon are very efficient disease management tools for anthracnose control. However, the registration of other fungicides for anthracnose may have additional benefits for the control of a spectrum of vine diseases. Whilst ziram is only effective against anthracnose; captan and chlorothalonil also have activity against downy mildew (Magarey *et al.* 1977, Thomson 1988). Chlorothalonil, dichlofluanid and fluazinam are useful in control of Botrytis (Emmett and Nair 1991, Nair pers. comm.). Captan is not currently registered in Australia, but is registered in most countries around the world including New Zealand (Taylor pers. comm.). Our data provides evidence of the efficacy of a broader range of fungicides for use against *E. ampelina* than are currently registered for use in Australian vineyards.

Acknowledgments

We thank Brian Wilkins and Kathy Clarke for expert technical assistance. The chemical companies listed in Table 1 are gratefully acknowledged for supply of fungicides. We also thank the Dried Fruits Research and Development Council and the Grape and Wine Research and Development Corporation for financial assistance.

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Table 1. Fungicides screened for pre-infection efficacy against grapevine anthracnose

Trade name	Active ingredient	Manufacturer	Expt. No.
Anvil 50SC	hexaconazole, 50g/L	ICI	1
Bravo 500F	chlorothalonil, 500g/L	Agchem	1 4
Captan 830W	captan, 830g/Kg	ICI	2 4
CGA 169374 250EC	difenoconazole, 250g/L	Ciba-Geigy	1
CGA 219417 250EC	CGA 219417, 250g/L	Ciba-Geigy	1
Euparen 500WG	dichlofluanid, 500g/Kg	Bayer	2 4
Folicur 250EC	tebuconazole, 250g/Kg	Bayer	3
Nustar 20W	flusilazole, 20g/Kg	Dupont	1
Rubigan 120EC	fenarimol, 120g/L	Schering	4
Shirlan 500SC	fluazinam, 500g/L	ICI	2 4
Sportak 450EC	prochloraz, 450g/L	Schering	1 3 4
Systhane 400W	mycobutanil, 400g/Kg	Hoechst	1
Tilt 250EC	propiconazole, 250g/L	Ciba-Geigy	1 3
Topas 250EC	penconazole, 250g/L	Ciba-Geigy	3
Trifmine 250EC	triflumizole, 250g/L	Ciba-Geigy	3
Ziram 800W	ziram, 800g/L	Agchem	1 2 3 4

Table 2. **Pre-infection efficacy of nine fungicides against grapevine anthracnose under *in vitro* conditions.**

Treatment	Dose (mg a.i./L)	Leaf discs infected[A] %
Ziram	1200	0.0a
Chlorothalonil	950	17.3b
Prochloraz	248	21.8b
Flusilazole	20	28.2b
Mycobutanil	44	43.3c
Difenoconazole	250	47.3c
Propiconazole	250	63.4cd
CGA 219417	250	61.0d
Hexaconazole	200	67.5d
Control		74.5d

[A] Same letters indicate means which are not significantly different using the pairwise LSD (P = 0.05).

Table 3. **Pre-infection efficacy of four fungicides against grapevine anthracnose under glasshouse conditions.**

Treatment	Dose (mg a.i./L)	Diseased leaves[A] %	Diseased internodes[A] %	Leaf area infected[A,B] %
Ziram	1200	28.3a	0.0a	0.2a
Dichlofluanid	1000	33.3a	0.0a	0.3a
Fluazinam	500	35.3a	0.0a	1.3a
Captan	1000	38.3a	0.1a	0.7a
Control		95.0b	50.0b	12.9b

[A] Same letters indicate means which are not significantly different at P = 0.01 as determined by LSD comparison.
[B] Re-transformed data presented.

Table 4. **Pre-infection efficacy of six fungicides against grapevine anthracnose under glasshouse conditions.**

Treatment	Dose (mg a.i./L)	Stem area infected[A] %	Leaf area infected[A] %
Ziram	1200	0.00a	0.02a
Prochloraz	248	0.06b	0.52ab
Tebuconazole	50	0.88b	0.88ab
Propiconazole	25	2.50b	1.12bc
Penconazole	25	1.44b	1.32bc
Triflumizole	90	1.70b	1.92bc
Control		2.10b	6.98d

[A] Same letters indicate means which are not significantly different as determined by LSD comparison at P = 0.05. Re-transformed data are presented.

Table 5. **Pre-infection efficacy of seven fungicides against grapevine anthracnose under field conditions.**

Treatment	Dose (mg a.i./L)	Stem area infected[A] %	Leaf area infected[A] %
Chlorothalonil	1500	0.003ab	0.006a
Dichlofluanid	1000	0.002a	0.006a
Ziram	1200	0.007ab	0.008a
Fluazinam	500	0.004ab	0.013ab
Captan	1040	0.017ab	0.013ab
Prochloraz	248	0.010abc	0.025bc
Fenarimol	24	0.038c	0.041c
Control		0.164d	0.200d

[A] Same letters indicate means which are not significantly different as determined by LSD comparison at P = 0.05. Re-transformed data are presented.

Table 6. **Phytotoxicity of three fungicides to *Vitis vinifera* cv Sultana applied 4 times on a fortnightly schedule under field conditions.**

Treatment	Dose (mg a.i./L)	Mean phytotoxicity rating per leaf Leaf number 1	2	3	4	5	6	Mean
Fenarimol	24	0.78	0.66	0.23	0.15	0.07	0.03	0.32
Chlorothalonil	1500	0.19	0.19	0.03	0.07	0.03	0.00	0.09
Prochloraz	248	0.04	1.04	0.04	0.00	0.00	0.00	0.02
Control		0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD P=0.05								0.16
P=0.01								0.25

Grape (Vitis vinifera 'Sultana')
Anthracnose: Elsinoe ampelina

(83)

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EVALUATION OF FUNGICIDES FOR CONTROL OF ANTHRACNOSE ON GRAPES, 1990: Eleven fungicide treatments were tested in two separate trials. Fungicides were applied to single vine plots arranged in a randomised complete block design and replicated six times. The experiments were conducted on six month old grapevines growing in a glasshouse. Seven and five fungicides were tested in trials 1 and 2 respectively with Ziram as the standard treatment. Each treatment was applied to one young vine shoot per plot by dipping in fungicide solution for 10 seconds. After 24 hours all treated vines and untreated controls were sprayed with a suspension of $5x10^4$ conidia per ml of Elsinoe ampelina and immediately enclosed in polyethylene bags for 48 hours. Disease was assessed on the five terminal leaves of each shoot 14 days after treatment.

In trial 1, all treatments significantly (P= 0.05) reduced disease incidence and severity. Sportak was the most effective treatment, while Sulfine provided poor disease control. Rubigan, Bravo, Dithane M45 and Benlate were not significantly different from Ziram. Sportak and Rubigan were phytotoxic causing leaf burn and senescence on young vine growth. In trial 2, all treatments reduced disease severity, but only Ziram and Delan significantly reduced disease incidence. Morestan, Rovral and Topsin M were less effective than Ziram. No phytotoxicity was observed in trial 2.

Treatment	rate per 100L	% diseased leaves	% leaf area infected rating*
Trial 1			
Sportak 45EC	55ml	0.0a**	0.00a***
Rubigan 120EC	20ml	13.3ab	0.54ab
Bravo 75W	200g	23.3ab	0.94 b
Dithane M45 80W	200g	30.0 bc	1.05 bc
Ziram 80W	150g	30.0 bc	1.14 bc
Benlate 50W	40ml	50.0 cd	1.63 cd
Sulfine 80W	300g	63.3 d	2.34 d
Untreated		93.3 e	4.59 e
LSD (P= 0.05)			0.91
Trial 2			
Ziram 80W	150g	20.0a	0.74a
Delan 75W	50g	33.3ab	1.03a
Topsin M 70W	200g	60.0 bc	2.79 b
Morestan 25W	50g	63.3 bc	2.39 b
Rovral 50W	100g	63.3 bc	2.99 b
Untreated		83.3 c	4.91 c
LSD (P= 0.05)			1.14

* Individual leaves were scored 0-10 with the aid of a diagrammatic key with 11 categories for % area of leaf infected with the following upper limits: 0%, 0.4%, 0.8%, 1.6%, 3.0%, 6.3%, 12.5%, 25%, 50%, 75% and 100%. The category score for the 5 leaves was summed and analysed by ANOVA with a square root transformation.
** Common letters in this column, within a trial indicate means that are not significantly different Duncans Multiple Range Test (P= 0.05).
*** Common letters in this column, within a trial indicate means that are not significantly different, LSD (P= 0.05).

Grape (Vitis vinifera 'Sultana')
Anthracnose; Elsinoe ampelina

(59)

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EVALUATION OF FUNGICIDES FOR CONTROL OF ANTHRACNOSE ON GRAPES, 1991: Six fungicides were applied to single vine plots arranged in a randomised complete block design and replicated seven times. The experiments were conducted on six month old grapevines growing in a glasshouse. Each treatment was applied to one young vine shoot per plot by spraying to runoff. After 24 hours, all treated vines and untreated controls were sprayed with a suspension of $5x10^4$ conidia per ml of Elsinoe ampelina and immediately enclosed in polyethylene bags for 24 hours. Disease was assessed on the five terminal leaves and internodes of each shoot 10 days after treatment.

Captan, Euparen, Shirlan and the standard treatment Ziram provided good disease control. Allisan and Sumisclex did not reduce disease incidence or severity. No phytotoxicity was observed.

Treatment and rate per 100L	% diseased leaves.	% diseased internodes	% leaf area infected[3]	
Ziram 80W 150g	17.1a[1,2]	5.7a[1,2]	0.32a[2]	(0.4)
Euparen 50WG 200g	20.0a	0.0a	0.35a	(0.4)
Captan 80WG 125g	23.6a	0.0a	0.49a	(0.6)
Shirlan 50SC 100ml	31.4a	0.0a	0.57a	(0.8)
Allisan 75W 100g	94.3b	43.9b	2.29b	(8.9)
Sumisclex 50W 75g	89.4b	43.9b	2.57b	(12.1)
Untreated	79.2b	36.7b	2.73b	(14.4)
LSD (P = 0.05)			0.63	

1. Means for % diseased leaves and internodes were compared by pairwise LSD.
2. Common letters within a column indicate means that are not significantly different. LSD (P = 0.05).
3. Individual leaves were assessed with the aid of a diagrammatic key with 11 categories for % area of leaf infected with the following upper limits: 0%, 0.4%, 0.8%, 1.6%, 3.0%, 6.3%, 12.5%, 25%, 50%, 75% and 100%. The percentage score for the 5 leaves was summed and analysed by ANOVA with a log transformation. Re-transformed values are presented in brackets.

Grape (Vitis vinifera 'Sultana')
Anthracnose; Elsinoe ampelina

(58)

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EVALUATION OF DEMETHYLATION INHIBITING (DMI) FUNGICIDES FOR CONTROL OF ANTHRACNOSE ON GRAPES, 199
Eleven fungicide treatments were tested in two separate trials. Fungicides were applied to single vine plots arranged in a randomised comple: block design and replicated seven times. The experiments were conducted on six-month-old grapevines growing in a glasshouse. Seve fungicides were tested in trials 1 and 2 with Ziram as the standard treatment. Each treatment was applied to one young vine shoot per plot b spraying to runoff. After 24 hours, all treated vines and untreated controls were sprayed with a suspension of $5x10^4$ conidia per ml of Elsino ampelina and immediately enclosed in polyethylene bags for 24 hours. Disease was assessed on the five terminal leaves and internodes of eac shoot 10 days after treatment.

In trial 1, all treatments reduced leaf disease severity, but only Sportak and Ziram significantly reduced leaf and internode disease incidence In trial 2, all treatments except for CGA 219147 reduced leaf area infected. Rubigan provided poor disease control and did not reduce leaf an internode disease incidence. Saprol, Tilt and CGA 169374 provided good disease control, except that Tilt did not reduce internode diseas incidence. Tilt and CGA 169374 also produced a high degree of leaf speckling which may indicate aborted infection. In both trials, Systhane Rubigan, Sportak and Tilt were phytoxic on young leaves causing necrosis, speckling, downcurving and stunting.

Treatment and rate per 100L	% diseased leaves	% diseased internodes	% leaf area infected[3]	
Trial 1				
Ziram 80W 150g	20.0a[1,2]	3.3a[1,2]	0.31a[2]	(0.4)
Sportak 45EC 55ml	51.4b	14.3a	0.95a	(1.6)
Nustar 20W 10g	91.4c	45.7b	1.94b	(5.9)
Bayfidan 25EC 10ml	96.6c	56.0bc	2.12b	(7.4)
Systhane 8OW 11g	94.2c	80.0c	1.85b	(5.3)
Anvil 50SC 40ml	100.0c	72.0bc	2.01b	(6.5)
Untreated	100.0c	68.3bc	3.22c	(24.0)
LSD (P=0.05)			0.84	
Trial 2				
CGA 169374 25EC 10ml	0.0a	5.0a	0.0a	(0.0)
Ziram 80W 150g	22.9b	0.0a	0.44a	(0.6)
Tilt 25EC 10ml	8.0ab	25.0ab	0.24a	(0.3)
Saprol 19EC 120ml	29.2bc	16.7a	0.64a	(0.9)
Rubigan 12EC 20ml	57.3cd	49.5b	1.68b	(4.4)
CGA 219147 25EC 10ml	91.4de	54.3b	2.84c	(16.1)
Untreated	85.0d	51.4b	2.88c	(16.8)
LSD (P=0.05)			0.86	

1. Means for % diseased leaves and internodes were compared by pairwise LSD.

2. Common letters in this column within a trial, indicate means that are not significantly different, LSD (P = 0.05).

3. Individual leaves were assessed with the aid of a diagrammatic key with 11 categories for % area of leaf infected with the followin upper limits: 0%, 0.4%, 0.8%, 1.6%, 3.0%, 6.3%, 12.5%, 25%, 50%, 75% and 100%. The percentage score for the 5 leaves was summe and analysed by ANOVA with a log transformation. Re-transformed values are presented in brackets.

Appendix 2 Residues of black spot fungicides

a) **Residues of four fungicides applied for control of grapevine anthracnose in a budburst to flowering spray program.**

R.D. Magarey, R.W. Emmett and G. Roberts.

Advanced draft to be submitted for publication in a scientific journal.

DRAFT

Residues of four fungicides applied for control of grapevine anthracnose in a budburst to flowering spray program.

R.D. Magarey[a], R.W. Emmett[a] and G. Roberts[b]

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Summary

Four fungicides ziram (Ziram®), dichlofluanid (Euparen®), fluazinam (Shirlan®) and captan (Captan®) were applied in a 5-spray program from budburst to flowering and a 3-spray program from budburst to 20-30cm shoot length stage in a Sultana vineyard at Irymple, Victoria. Bunch samples were collected at 5 intervals after the last application in the 5-spray program and at 2 intervals after the 3-spray program and analysed for residues of the fungicides applied. For all treatments the 3-spray program did not result in detectable residues at harvest. However, some samples from vines sprayed 5 times with captan or ziram contained residues at concentrations between 0.07 - 0.1 mg/kg at harvest.

Introduction

Control programs for grapevine anthracnose or black spot usually begin at budburst and can continue until berry set (Emmett *et al.* 1992). Many fungicides used in anthracnose spray schedules may also be used during this period for the control of other diseases such as Botrytis rot and downy mildew. Residue studies were conducted on four fungicides with potential for anthracnose control, including ziram, the main fungicide currently used by the Australian grape industry. For each fungicide a 3- and a 5-spray program were applied to establish a degradation curve for residues on bunches and to compare an early season program with one that continues to flowering.

Method

Four fungicides were applied to runoff with a handline sprayer to two vine plots of *Vitis vinifera* cv Sultana in a vineyard near Mildura, Victoria. Seasonal conditions were drier than average during 1991/92 with rainfall below average in 4 out of 6 months from September to February (Figure 1). The plots were arranged in a randomised block design and treatments were replicated four times. Two vine buffers and alternate buffer rows were used to reduce spray drift. The treatments applied are listed in Table 1. For each treatment in the five spray program approximately 500g of bunches were sampled by selecting at random bunches from each cordon of both vines. Samples were taken at 7,14,21,28 and 97 days (harvest) after the application of the last spray. Samples from the vines treated with the 3-spray program were collected 35 and 126 (harvest) days after the application of the third spray on 9 October 1991.

Samples were analysed for residues at each sampling interval by gas chromatography (ziram, dichlofluanid and captan) or high performance liquid chromatography (fluazinam). A limit of detection of 0.01 mg/kg was achieved for each analyte. Samples of the formulations of each product and tank mixes for each spray were also analysed.

Results

Formulation

All formulations sampled contained the active within ±7% of the concentration stated on the label, except for Euparen which was 64% higher than the stated concentration. Studies are continuing in an attempt to resolve this discrepancy.

Tank mixes

Because of a technical error, tank mixes were not analysed until seven months after sampling. During this period they were kept at 2°C. All tank mixes contained only 50-90% of the expected concentration. The stability of the products under these conditions is unknown but it is possible that considerable degradation occurred during storage.

Residues on berries

The 3-spray program did not result in detectable residues at harvest. Captan and ziram applied in a 5-spray program produced detectable residues at harvest between 0.07 and 0.10 mg/kg in some bunch samples. Residues of all fungicides decayed significantly (P=0.01) over the 21 day sampling period (Figure 2). For each treatment the level of residues 28 days after the fifth spray in the 5-spray program was not significantly different from the level of residues obtained 35 days after the third spray in the 3-spray program. Berries from untreated plots did not contain residues of any of the fungicides, except captan. Three replicates from untreated plots contained 0.01 to 0.13 mg/kg of captan seven days after the fifth spray. Only one replicate had detectable captan residues of 0.01 mg/kg 14 days after the fifth spray.

Discussion

The 3-spray program (budburst to 20-30cm stage) did not result in detectable residues at harvest. A 5-spray program (budburst to flowering) resulted in detectable residues at harvest for ziram and captan. Captan residues in fruit from untreated vines are an indication that the size of buffers should be increased in future experiments. Since residues from both programs were not significantly different ($P > 0.05$) at a similar interval after the application of the last spray in each program, the interval between harvest and application has a greater effect on residue levels than the growth stage at the time of application. Similarly, Precheur *et al.* (1992) found for a range of protectant fungicides, the total amount of fungicide applied during the growing season and not just the time of last application before harvest appeared to determine residue levels in processing tomatoes. These findings indicate that the number of sprays applied throughout the season is likely to have a large influence on fungicide residues in grapes. It also highlights the need to maximise the interval between spraying and harvest by concentrating on early season programs if control is necessary.

Acknowledgments

The authors thank Peter Franz and Brendan Stevenson for assistance with the statistical analyses and Brian Wilkins for expert technical assistance. The contribution of the chemical companies listed in Table 1 is acknowledged for the supply of the fungicides tested.

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Precheur, R.J., Bennett, M.A., Riedel, R.M. Wiese, K.L. and Dudeck, J. (1992). Management of fungicide residues on processing tomatoes. Plant Disease 76:700-702.

Table 1. Fungicide treatments and their residues on grape berries at harvest.

Treatment	Product*	Company	Rate of product per 100L	Application** 1 2 3 4 5	Mean residue (mg/kg)
ziram	Ziram 800W	Incitec	150g	* * *	0.00
ziram	Ziram 800W	Incitec	150g	* * * * *	0.03
captan	Captan 830W	ICI	125g	* * *	0.00
captan	Captan 830W	ICI	125g	* * * * *	0.04
fluazinam	Shirlan 500SC	ICI	100ml	* * *	0.00
fluazinam	Shirlan 500SC	ICI	100ml	* * * * *	0.00
dichlofluanid	Euparen 500WG	Bayer	200g	* * *	0.00
dichlofluanid	Euparen 500WG	Bayer	200g	* * * * *	0.00

* W = Wettable powder, SC = suspension concentrate, WG = water dispersable granules.

** Application dates corresponding to 1,2,3,4,5 are respectively 13 September (12 days after budburst), 24 September, 9 October, 22 October and 7 November (flowering).

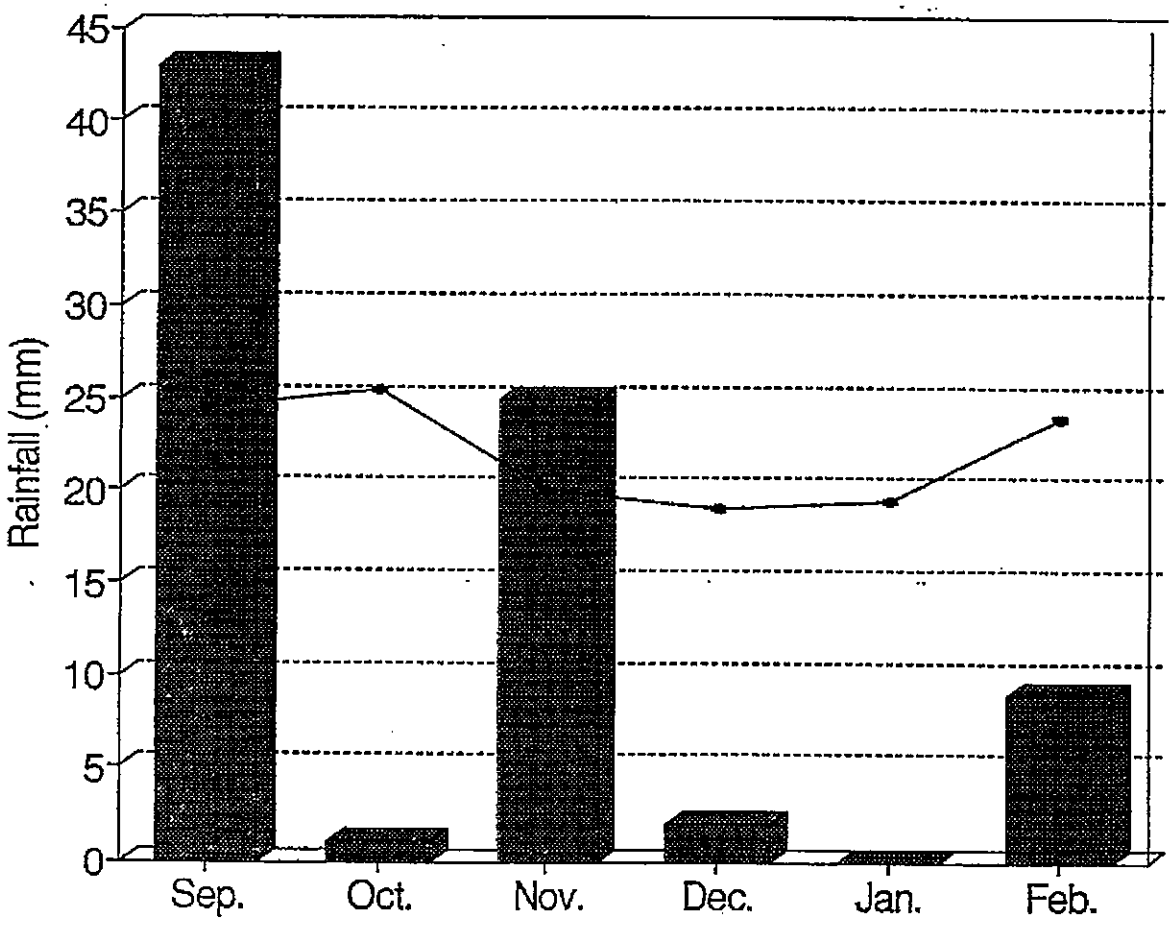


Figure 1. Rainfall during the 1991/92 growing season (bars), in comparison with a 30 year average (line).

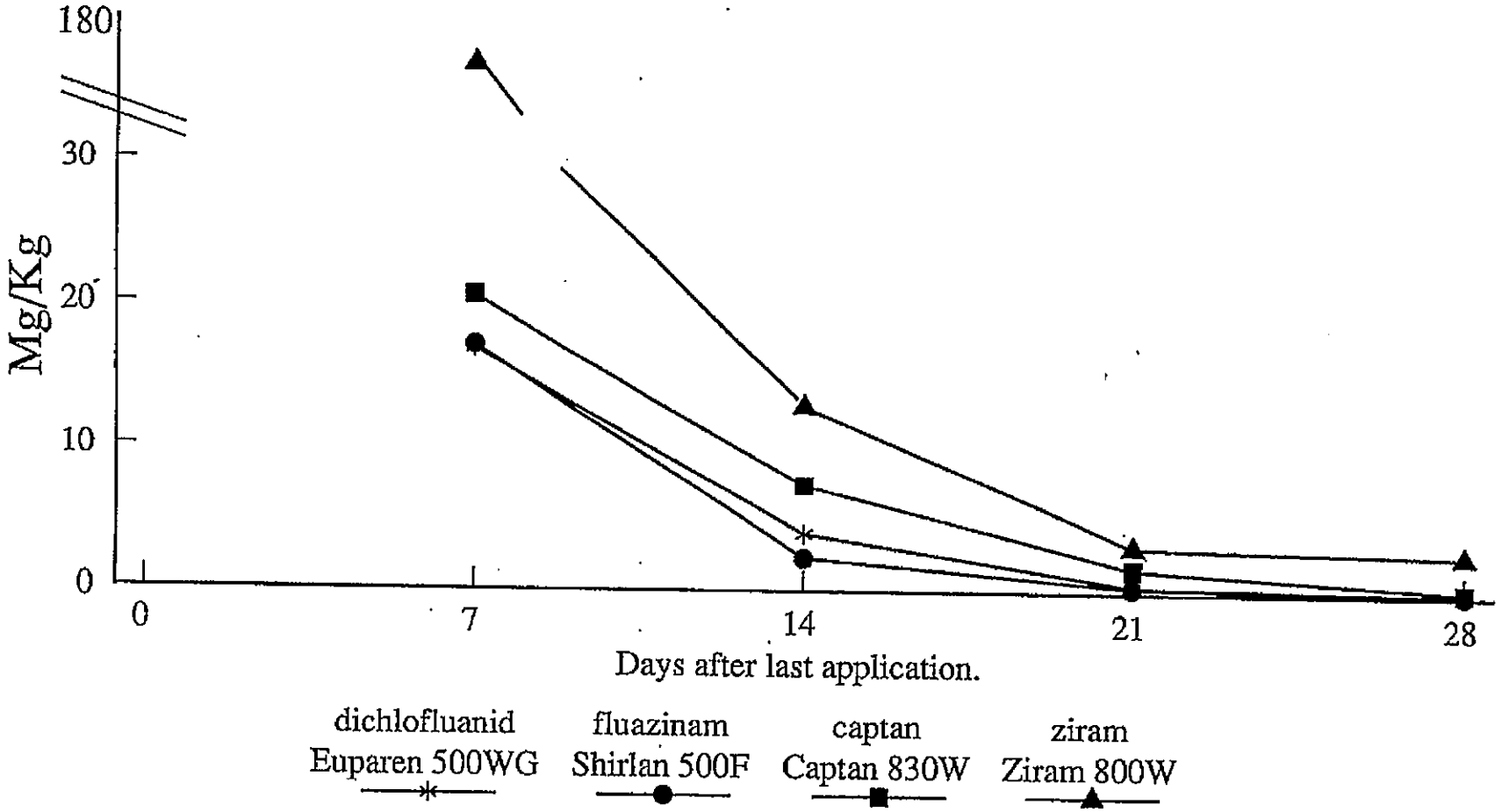


Figure 2. Residues in berries of four fungicides applied in a fortnightly program from bud burst to flowering 7,14,21 and 28 days after application.

Appendix 3 Literature review: Anthracnose of grapevines

a) **Anthracnose of grapevines; a review.**

R. D. Magarey, B. E. Coffey and R. W. Emmett

Manuscript of paper accepted for publication in *Plant Protection Quarterly*

Anthracnose of grapevines, a review.

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Summary

Grapevine anthracnose (also known as grapevine black spot) is found in most grape growing regions of the world. The causal agent is the ascomycete *Elsinoe ampelina*, although the sexual stage appears to be absent in many countries. The pathogen persists as sclerotia on diseased vine canes for 3-5 years and these germinate to produce conidia, the primary inoculum in most regions. Only actively growing tissues are infected and rain splashed conidia require a certain duration of surface wetness at a given temperature for infection. Rainfall is the main environmental determinant of disease severity. In Australia, the dithiocarbamate fungicides have provided effective control since the 1950's. Control of the disease is critical when frequent periods of rainfall occur in the first two months after budburst. In climates with relatively low spring rainfall the prospects for reactive spraying based on a disease forecasting system are good. The system would use weather data to identify infection periods and in conjunction with climatic data, cultivar susceptibility, vineyard observations and vine growth stage produce forecasts of the likely rate of disease increase, the risk of crop loss and the need for control treatments.

Distribution and importance

Anthracnose or black spot of grapevines, caused by *Elsinoe ampelina* Shear, probably originated in Europe (Shear 1929), but is now present in most grape growing regions of the world (Anon 1978). Countries where the disease has been reported include Australia (de Castella and Brittlebank 1918), New Zealand (Brook 1973), U.S.A. (Loucks 1936), India (Suhag and Grover 1972), South Africa (du Plessis 1940), China (Zhang and Huang 1990), Japan (Ozoe *et al.* 1972), Uruguay (Mazzei Patrone 1950), and Argentina (Anon 1964).

The incidence of the disease varies greatly and is mainly influenced by the amount of precipitation during the growing season. In the U.S.A. for example, anthracnose is of economic importance in the wet eastern states such as Florida, but does not occur on the drier west coast (Mirica 1988). On the other hand in sub-tropical India, the disease is widespread in most grape growing regions (Suhag and Grover 1977) while in South Africa it occurs in summer and winter rainfall districts (Boelema 1968). The historic importance of anthracnose is highlighted by the extreme measures used for its control e.g. swabbing vines with sulphuric acid (Taylor 1954). In the past, anthracnose has caused widespread damage to grapevines in many regions and is still an important disease in countries such as India (Suhag and Grover 1972).

In Australia, anthracnose was first recorded in New South Wales in the late 18th century (Gregory, 1988) and has since been reported in all mainland States (de Castella and Brittlebank 1918, Gay Brereton and Hamblin 1922, Coombe 1953, Shea 1961, Harvey 1965). Outbreaks have caused serious crop loss in Sunraysia (Victoria and NSW), the Murrumbidgee

Irrigation Area (NSW), and the Riverland (South Australia), as well as other regions (de Castella and Brittlebank 1918, Manuel 1928, Coombe 1953). In 1918, 100% crop loss was reported on some properties in Mildura and injury to canes resulted in poor crops in the following season (de Castella and Brittlebank 1918). In Victoria serious outbreaks occurred in 1916-1917, the early 1930's, 1947, the early 1950's and 1975-76 (de Castella and Brittlebank 1918, Taylor 1954, R.W. Emmett unpublished data). In Australia control measures introduced during the 1950's have been highly successful in reducing the severity and occurrence of outbreaks. In commercial vineyards in Western Australia the disease has almost been eliminated (Harvey 1965).

Symptomology

Leaves

Leaf symptoms first appear 3-7 days after primary infection (Brook 1973). On young leaves, the first signs of disease are small, faint circular chlorotic lesions. These quickly turn brown, increase in size and develop a reddish margin. As the leaf matures, the centres of lesions dry out and become ash coloured. With time, lesions develop a characteristic "shot hole" appearance.

Shoots, petioles, and tendrils

Lesions on the shoots, petioles and tendrils of grapevines are more appropriately classified as cankers. They begin as tiny dark brown indentations which darken, increase in size, and elongate. The margins of the cankers are raised and black, while their centres become sunken and ash coloured. Shoots, petioles, or tendrils can be girdled and killed by large cankers. Diseased canes are easily broken when they are wrapped onto trellis wires during pruning. On hardened vine tissues, solitary cankers appear swollen and knuckle-like while the surface of cankers that have coalesced is dark and rough like charred cork. During sporulation, the centre of cankers becomes pinkish-white.

Berries

Infected berries develop small round purple-black lesions that increase in size with berry growth. The centres of these lesions turn pinkish-white following sporulation. This symptom is called birds-eye spot in some countries. Severe crop loss can occur if bunch stems are girdled and killed.

Causal organism

References to anthracnose date back to the writings of Theophastrus and Pliny in ancient Rome, making it one of the oldest known diseases of plants (Vialla in du Plessis 1940). However, it wasn't until 1874 that the conidial stage of the fungus was described in detail as *Sphaceloma ampelinum* by de Bary (Shear 1929). Later, Gouirand and Bergeron, in 1897 illustrated the formation of conidia and sclerotia (Jenkins and Bitancourt 1943). During the late nineteenth century studies of the fungus resulted in a variety of synonymous names such as *Torula meyeni* Ber. and Trev., *Ramularia meyeni* Gar. and Catt., *Gloesoporium ampelophagum* (Pass.) Sacc., *Manginia ampelina* V. and P. (Shear 1929, Sivanesan and Critchett 1974 and de Castella and Brittlebank 1918). Nevertheless, the conidial stage of the fungus is still widely recognised as *Sphaceloma ampelinum*. Some authors considered the

fungus polymorphic (Vialla and Pacotet in Anderson 1956) although Shear (1929) was unable to confirm this.

The sexual stage of the fungus was described as *Elsinoe ampelina* de Bary (Shear). It was considered to belong to the genus *Elsinoe* since it is very similar to the sexual stage of the fungus causing anthracnose of raspberries and blackberries which was described by Burkholder (Shear 1929). The sexual stage does not occur as regularly as the conidial stage and has not been found in countries such as Britain (Butler and Jones, 1949), India (Suhag and Grover, 1972), South Africa (du Plessis 1940) and Australia. The reason for this absence has not been identified, although it may be related to specific winter conditions (Shear 1929) or the lack of suitable mating types.

Sivaneson and Critchett (1974) and Mirica (1988) provide morphological descriptions of the fungus. Ascospores are hyaline, 3-septate and are 15-16 x 4-5 µm. Asci are eight spored usually globose or elliptical and distributed irregularly in the upper part of the ascoma. Ascomata are globose, separate or aggregated, pseudoparenchymatous, epidermal to subepidermal. The germination of ascospores produces lesions which give rise to the conidial stage. Conidia are hyaline , one-celled and 4-7.5 x 2-3.5 µm. They have mucilaginous walls which allows them to readily adhere to substrates, (e.g. leaves) in the presence of water (Mirica, 1988). Conidia are produced most prolifically in acervuli on numerous short cylindrical conidiophores at the edge of lesions. In autumn, sclerotia form when production of acervuli ceases. Different strains of the fungus have been reported (Cheema *et al.* 1978, Kore and Gurme 1979, Suhag *et al.* 1982).

Epidemiology

Anthracnose is most destructive in humid hot climates, and is devastating in parts of India. Free water is required for most of the processes involved in disease development; without it primary sporulation, spore dispersal and infection does not occur. Although sporulation on active lesions does not require free water, it increases with humidity. Anthracnose can develop across a broad temperature range, but it is rarely a problem in regions where spring rainfall is relatively low (Mirica 1988).

Overwintering

The fungus persists on shoots, petioles and bunch stalks as sclerotia which are formed from late summer to winter as plant tissue hardens (du Plessis 1940). In Australia, formation of conidiophores ceases in January or February, and sclerotia are produced instead (de Castella and Brittlebank 1918). It is not known exactly what factors are responsible for this change although it is probably a combination of hot dry weather and the hardening of canes. Suhag and Grover 1982 found that the fungus remained viable on diseased canes, whether present on the vine or as prunings on the ground or 3-5 cm under the ground. Sclerotia on live canes had a higher percent viability than those on prunings on the ground, which in turn was higher than sclerotia on prunings 3-5 cm under the ground. Sclerotia on canes can be sources of inoculum for up to 2-5 years if conditions for primary infection fail to occur (Paufilova 1950, Brook 1992). The fungus may also overwinter on infected berries on the vineyard floor (Mirica 1988). Infected leaf debris is also a source of overwintering inoculum, however persistence of *E. ampelina* is greater on canes (Suhag and Grover 1972).

Primary sporulation

Overwintering sclerotia produce conidia that can cause primary infection as soon as susceptible host tissue is present. More rarely, ascospores may also cause primary infection (Anderson 1956). Thorough wetting of cankers is required in spring for sporulation, and as this can occur at low temperatures, the disease may spread in early spring even in cool climate vineyards (Anderson 1956). At temperatures above 2°C, 24 hours of wetness results in abundant sporulation, although 20°C is the optimum (Mirica 1988, du Plessis 1940). The conditions required for primary sporulation are unlikely to be critical since overwintering sclerotia from field vines produce conidia with little or no moist incubation (Brook 1973, R.D. Magarey unpublished data).

Spread

Spread of the disease is mainly by conidia which are dispersed in water during rainfall or overhead irrigations of 2mm or more (Mirica 1988). As a result, the spread of the disease is primarily confined within a vine or to nearby vines. However, rain-splashed conidia may cause infections up to 7 m away from the source of inoculum (Brook 1973). The disease may also spread by conidia carried on the feet of birds or on agricultural machinery, or by diseased planting material. Disease spread may also occur from wind-borne ascospores where the ascomata of the fungus are present. However, little is known about the range of dispersal by this means.

Infection

Tissue wetness is essential for infection. Conidial germination and the infection of vine tissues occurs at temperatures ranging from 2°C to 40°C, the optimum temperature being 30-35°C, (Suhag and Grover 1977, Virk and Grover 1979, Mirica 1988). The influence of light and humidity on infection is unclear. The duration of tissue wetness required for infection varies with the temperature. For severe infection 1.5 hours of tissue wetness is required at 30°C, 3-4 hours at 21°C, 4-7 hours at 16.5°C, and 7-10 hours at 12°C (Brook 1973, R.D. Magarey unpublished data).

Conidia of *E. ampelina* will survive interruptions to leaf wetness of at least two hours (Magarey unpublished data). This is important when considering the combined effects of two or more wetness events. Ascospores germinate and infect vine tissue at temperatures ranging from 2-32°C (Mirica 1988). However little else is known about ascospore behaviour and periods of surface wetness required for infection.

Incubation

The incubation period for anthracnose varies with temperature. After infection, expression of symptoms requires about 13-14 days at 2°C, 7 days at 12°C, 5 days at 16°C, and as little as 3-4 days at temperatures above 21°C (Brook 1973, Suhag and Grover 1977, Mirica 1988).

Secondary sporulation

Disease spread can be rapid, because new conidia are produced within 1-5 days after lesions become visible (Brook 1973). Sporulation reaches a maximum when the diameter of the lesion is about 1mm (Brook 1973). Leaves infected early in the season cease to produce conidia by summer and early autumn, but cankers on stems and recently infected leaves continue to sporulate (Brook 1973). In culture, the optimum temperature for growth and sporulation of the fungus is 30°C (Kore and Gurme 1978, Virk and Grover 1979). High humidity greatly increases sporulation. Kore and Gurme (1978) found that in culture, optimum sporulation occurs above 80% RH but limited sporulation still occurs at 30% RH. Light has little effect on sporulation. Kore and Gurme (1978) found conidial formation in culture occurred in continuous light and in diffused light but was greatest in continuous darkness. Nothing is known about the environmental conditions required for ascospore production.

Host susceptibility

Elsinoe ampelina is only known to infect *Vitis* species, although susceptibility to the fungus varies widely between cultivars. Species of *Vitis* native to the eastern United States of America are predominantly resistant to anthracnose and provide a source of resistant germplasm for grapevine breeders (Mortenson 1981). The *V. vinifera* cultivars Sultana, Waltham Cross, Ohanez are highly susceptible, while Shiraz and Cabernet Sauvignon are highly resistant (Jennings 1953, Dang and Daulta 1982, Yadav and Nirwan 1981, Mortenson 1981 and Goyal *et al.* 1971).

Effect of tissue age

The decline in tissue susceptibility with age is another important factor affecting the spread of the disease. Young grapevine tissues are more susceptible to infection while older tissues are highly resistant or immune (Brook 1973, Suhag and Grover 1977). When leaves and internodes are fully expanded, the rate of infection is very low (Figure 1). Also necrotic lesions reach a much greater size on young leaves than they do on older leaves (Suhag and Grover 1977). Similarly, Brook (1973) noted that berries become highly resistant to infection although not immune, when they reach a soluble solid content of 5-7%. The mechanism of resistance to anthracnose remains unclear. Various workers have examined the role of biochemical compounds in disease resistance. Kansal and Lal (1978) found increased levels of phospholipids in diseased leaf tissue, but reduced phospholipid content in the leaf overall. Daulta and Chauhan (1981) correlated disease intensity with concentration of reducing sugars and total phenols for nine cultivars of grapevine. There was only a small positive correlation for reducing sugars but a strong negative correlation for total phenols. Many anti-fungal compounds or phytoalexins are based on phenolic compounds (Salisbury and Ross 1985).

Effect of tissue type
Susceptibility to anthracnose differs considerably with tissue type. Suhag and Grover (1972) found that leaf material was more susceptible to infection than stems of the cultivar Thompson Seedless (syn. Sultana). There appears to be no consistent relationship in susceptibility of types of tissue. Datar and Ashaputre (1985) for example found that fruit of cultivars such as Country Bangalore, Calashil, and Husaini Black Kabuli was susceptible while leaves were moderately resistant. The reverse was found with the cultivars Rose of Peru, Waltham Cross, and Ruby Red.

Genetics of resistance
The inheritance of anthracnose resistance was investigated by Mortenson (1981). Mortenson proposed a trigenic hypothesis for resistance that involved two dominant genes for susceptibility and a single dominant gene for conditioning resistance with independent inheritance of each gene. This work was based on earlier studies by Fennell (1948) who stated that resistance was conditioned by multiple factors. Datar and Ashaputre (1985) also investigated the source of resistance and noted differential reactions to the leaf and fruit infection. They considered that resistance of leaves and berries was governed by two separate genes.

Control

Topography can affect the incidence and severity of anthracnose because of its effect on temperature, humidity and rainfall. Refatti (1949) noticed that vines grown on a hillside in the Pergine district of Italy escaped serious damage while other vines suffered between 10 and 100% crop loss. Moreover, low lying areas within a vineyard where dew persists or drainage is poor may be more prone to disease (de Castella and Brittlebank 1918). Cultivar selection is important in areas or climates prone to the disease.

Canopy management
Vine trellising systems can reduce the incidence of disease and may be a method for reducing anthracnose in some vineyards. Vine cultivar and trellis combinations that allow growing shoots to touch the ground and promote vegetative growth have higher disease incidences (Suhag and Daulta 1981).

Removal of canes with cankers will reduce the amount of overwintering inoculum present in the following season. However sufficient buds should be left for the next crop (Emmett 1976). Minimal pruning techniques can encourage the build up of inoculum of pathogens that persist in canes such as *Phomopsis viticola* Sacc. (Pscheidt and Pearson 1989).

Fungicidal control

Historically, the control of anthracnose has involved the treatment of vines during dormancy to reduce the overwintering inoculum. Dormant treatments were applied as either sprays or swabs, just prior to bud burst. Before this time the majority of overwintering sclerotia are small and are protected by layers of host cuticle (de Castella and Brittlebank 1918). Fungicides that have been used as dormant sprays in the past include copper sulphate, lime sulphur, and Bordeaux mixture (du Plessis 1940, Manuel 1928). Swabbing treatments involved painting or daubing the vines with solutions of sulphuric acid, Bordeaux mixture or iron sulphate (Gay Brereton and Hamblin 1922). The high labour costs involved, the hazardous nature of some of the compounds and the availability of safer more effective treatments has made these practices obsolete.

Since young vine tissue is more susceptible to infection than older vine tissue, most modern spray programs start at budburst and continue at 10-14 day intervals for about 4 weeks (Coombe 1955, Harvey 1965, Boelema 1968, Anon 1971, Emmett 1980). If weather conditions at flowering favour disease development, further sprays may be recommended (Harvey 1965, Boelema 1968).

During the growing season, Bordeaux mixture and other copper based fungicides have been used widely in control (Winkler *et al.* 1974, Gupta, 1987, Shoi and Sridhar 1972). However, as copper based fungicides can be phytotoxic to young growth, they have been replaced by the more effective dithiocarbamate fungicides which are now used widely in Australia, U.S.A., and South Africa (Coombe 1953, Taylor 1954, Boelema 1968). The success of the dithiocarbamates is evident in Australia where routine early season sprays of ziram or thiram have been so effective that the disease is no longer a serious problem. Other multisite or protectant fungicides are also effective but many other fungicides used for other grape pathogens provide little or no control of anthracnose (Table 1).

Concluding remarks

Grapevine anthracnose is readily controlled by a range of protectant fungicides. However, with the increasing emphasis on minimal chemical use and residues in food and food products nowadays, it is important that the number of fungicide applications in control programs is kept to a minimum. Spraying for anthracnose control can be avoided in most years in districts with relatively low spring rainfall as free moisture is required for infection.

A management shift from routine spray to reactive spray programs requires accurate disease forecasting. Reliable forecasts are obtained when accurate epidemiological models are used in combination with site-specific weather data. The components of a forecast model could be as follows: i) Selection of a routine or reactive spray program based on climatic data and cultivar susceptibility; ii) Identification of infection periods using records of leaf wetness, temperature, humidity and rainfall; iii) Estimation of the incidence of disease from calculations of infection periods, vineyard observations and spray records; iv) Calculation of the rate of disease increase based on the estimated disease level and vine growth stage, including leaf and berry susceptibility; v) Assessment of spray need as "low" - where a

fungicide for anthracnose control should be included in the tank mix during other spraying operations or as "high" where a spray for anthracnose control should be applied regardless of other spraying operations. The absence of an effective post-infection fungicide limits the use of a reactive strategy to vineyards with low disease pressure. The prospects of a reliable forecast system are high because the epidemiology of *E. ampelina* is well understood. The system would need accurate vineyard observations and weather data to produce reliable forecasts. The integration of epidemiological models for a range of diseases and pests into a computer driven decision aid device for grapegrowers has the most potential for providing low input control strategies for anthracnose.

An aspect of the biology of the disease requiring further study is the reason for the absence of the sexual stage from many parts of the world. This is important since ascospore production could have considerable influence on the spread of disease and the potential for the pathogen to develop resistance to fungicides.

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Table 1. Summary of fungicide efficacy against anthracnose

Fungicide or Fungicide Class	Activity	Reference
dithiocarbamates	Excellent to Good	Emmett *et al.* 1981
captan/captafol	Excellent to Good	Emmett *et al.* 1981
dichlofluanid	Excellent	Magarey and Emmett 1992a
fluazinam	Excellent	Magarey and Emmett 1992a
chlorothalonil	Good	Hopkins 1974, Magarey *et al.* 1977
DMI*	Fair[P]	Magarey and Emmett 1992b, Magarey unpublished data
copper	Fair to Poor	Coombe 1953, Emmett *et al.* 1981
lime sulphur	Fair to Poor	Coombe 1953
benzimidazoles	Fair to Poor	Coffey *et al.* 1991
sulphur	Poor	Coffey *et al.* 1991
dicarboximides	Poor	Coffey *et al.* 1991, Magarey and Emmett 1991
metalaxyl	Poor	Moore and Schroeder 1983

Excellent - exhibits excellent control
Good - exhibits good control
Fair - exhibits some control
Poor - has little or no controlling effect
P - problem associated with phytotoxicity during early season use particularly on sensitive cultivars e.g. Sultana

*DMI - Demethylation inhibiting fungicide.

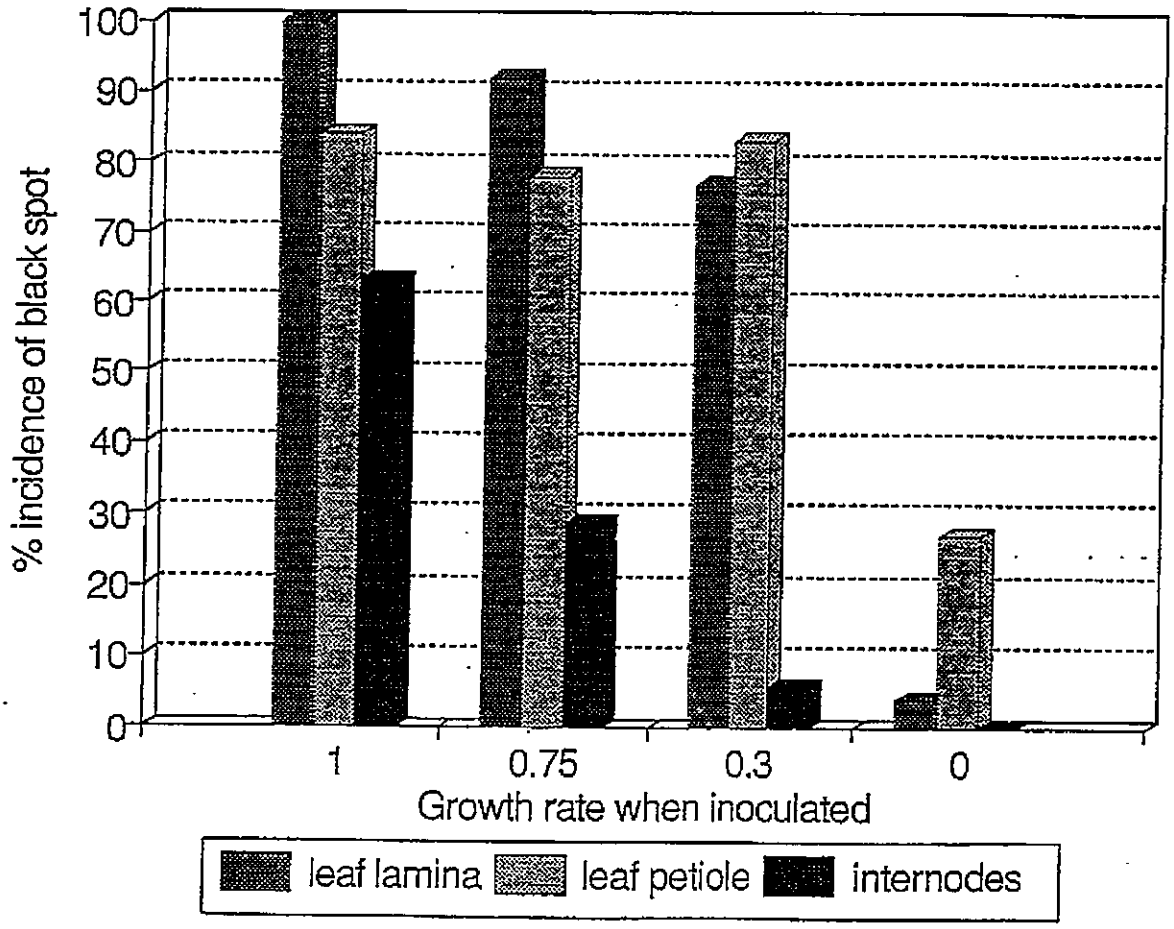


Figure 1. Differential infection of leaf lamina, leaf petiole and stem tissue on *Vitis vinifera* cv Palomino inoculated with *Elsinoe ampelina*, as a function of growth rate. Tissue is highly susceptible to infection when young and rapidly expanding. Susceptibility declines as growth rate decreases and is very low when tissue has fully expanded (after Brook 1973).

Appendix 4.

a) **Spread of grapevine black spot (anthracnose) caused by *Elsinoe ampelina* in vineyards in inland Australia.**

R. D. Magarey and R. W. Emmett

Advanced draft to be submitted for publication in a scientific journal.

Spread of grapevine black spot (anthracnose) caused by *Elsinoe ampelina* in inland Australian vineyards.

DRAFT

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Summary

Spread of grapevine black spot requires frequent periods of rainfall in the first two months after budburst. Moisture is required for spore dispersal and infection. The spread of black spot in vineyards at Irymple, Victoria was recorded over a two year period. In 1991/92 seasonal conditions were dry and only one infection period occurred before flowering. No disease was observed except for trace amounts on vines with resident overwintering cankers. In 1992/93 frequent periods of rainfall occurred throughout spring and seven infection periods occurred before flowering. In most commercial vineyards in the Sunraysia/Riverland districts levels of overwintering inoculum are low. In these vineyards spread of disease is slow, and prior to flowering is mainly confined to vines with cankers or adjacent vines. If favourable conditions continue after flowering, disease increases rapidly and spreads throughout the vineyard. Typical incubation periods at Irymple are 5-7 days depending upon temperature. There is no evidence of the presence of the sexual stage of *Elsinoe ampelina* in vineyards of South Eastern Australia.

Introduction

Grapevine black spot (anthracnose) caused by *Elsinoe ampelina* Shear, is an infrequent disease in inland Australian vineyards with outbreaks occurring only about once every 20 years (Magarey, in press). This is primarily due to the requirement of moisture for infection and spread. *Elsinoe ampelina* infects only young expanding tissue (Brook 1973). Only a minority of cultivars are susceptible to black spot, mainly Sultana and tablegrape cultivars while most wine varietals are relatively resistant (Hart *et al.* 1993). The sexual or ascigerous stage of *Elsinoe ampelina* does not occur regularly and has not been found in many of the world's viticultural regions (Magarey *et al.* in press). The reason for this absence has not been identified but may be related to specific winter conditions (Shear 1929). The presence of the ascigerous stage in Australia would have implications for disease spread and resistance to fungicides.

Since the introduction of dithiocarbamate fungicides such as ziram and thiram, the incidence of black spot in commercial vineyards has been low. Most spray schedules for black spot recommend the application of fungicides every 10-14 days from 50% budburst until berry set. A survey of grower spray practices revealed that the average grower in the Sunraysia region of Victoria during season 1991/92 applied 1.5 sprays specifically for black spot control

even when conditions were unsuitable for black spot spread and development (Magarey, unpublished).

The development of post-infection fungicides and reactive spray strategies for the control of downy mildew (*Plasmopara viticola*) has implications for black spot management. A conventional spray program for downy mildew begins at 20-30cm shoot stage and usually continues until berries are pea size. With the exception of copper based fungicides, most pre -infection fungicides used for routine control of downy mildew also control black spot (Magarey *et al.* 1993). If routine spray programs for downy mildew are used less frequently the incidence of black spot in commercial vineyards may rise. To confidently withhold spraying for control of black spot and to maximise management efficiency, more information is required on the spread and development of black spot in Australian vineyards. The purpose of these studies was to determine the influence of low levels of overwintering inoculum on crop loss given the onset of conditions favourable for disease spread.

Methods

Infection periods

Infection periods for the seasons 1991/92 and 1992/93 were identified by comparing weather data with an epidemiological model based on Brook (1973), Mirica (1988) and Magarey (unpublished). Rainfall and temperature records were collected from the Bureau of Meteorology's weather station at Mildura, while leaf wetness was measured with a string recorder at the Sunraysia Horticultural Centre, Irymple, Vic. Infection was considered to have taken place if rainfall was greater than 2mm during a period when the recorded hours of leaf wetness exceeded the minimum period at the corresponding mean temperature (Figure 1).

Spread studies

All spread studies were conducted in undervine irrigated *Vitis vinifera* cv. Sultana vineyards at Irymple Victoria. Assessments of black spot in the vineyards were made at three to four weekly intervals in two seasons. Detailed observations were made in a vineyard with a history of black spot disease. Before September 1990 this vineyard was disease free. During Spring of 1990 disease was introduced into the vineyard by inoculating vines on a grid pattern. The vine rows were 3.4m apart, with a 2m spacing between the vines. Every third and fourth vine was inoculated in every second row. Diseased canes were retained overwinter. In Spring of 1991 artificial misters were switched on at fortnightly intervals for 24 hours to promote disease spread. The level of disease was assessed on November 11 and 20, 1991.

In 1992, a total of 30 vines were assessed at each of the three sampling periods; November 4, December 10 and December 31. Six rows were sampled, three containing inoculated vines and three rows without inoculated vines. In rows containing inoculated vines, five vines were selected at random with at least two being inoculated vines and at least two being vines adjacent to inoculated vines.

At each sampling time the number of diseased leaves per shoot on 10 shoots on each of the 30 vines was counted. The incidence of black spot on leaves was calculated by dividing the number of diseased leaves per shoot by the average number of unfolded leaves per shoot. Shoot incidence was the proportion of diseased shoots. Five bunches per vine were assessed and scored with a diagrammatic key for severity on the based of percent bunch area diseased (Horsfall and Barratt 1945)

A vineyard survey of 10 rows, each at 5 row intervals for black spot was also conducted from November 20 - 25, 1992. In each row, 34 vines were inspected and the number of shoots with black spot was recorded on a cordon basis. The total number of diseased shoots per row was then divided by the total number of shoots per row and graphed on the basis of row distance from the known source of black spot infection in the previous season.

Incidence and severity of black spot on bunches at harvest (February 22, 1993) was assessed on six samples of 10 bunches and 10 leaves from each inoculated vine and from adjacent vines within and across the row and a general sample from a block of vines, three rows distant. The number of bunches per vine and samples of bunch weights at different distances from inoculated vines was compared by ANOVA (Genstat V).

Incubation period

Elsinoe ampelina spore suspensions were prepared by incubating cankers or lesions on canes in a humid atmosphere for 48 hours. Spores were washed off the lesions, diluted to a concentration of $1x10^4$ conidia per ml and sprayed onto young actively growing shoots, which were then enclosed in polythene bags for 24-48 hours. Shoots were observed daily or in some cases at two day intervals and the development disease symptoms was recorded.

Ascigerous stage

To explore the possibility of the presence of the perfect state of *Elsinoe ampelina* in Australia a spore trap connected to a vacuum pump was used to search for ascospores. Pieces of canes with cankers were incubated for 24 hours and the placed inside the spore trap. Spores were collected on a microscope slide coated with a thin layer of vaseline placed inside the trap venturi. The procedures were repeated on eight occasions from June 25, 1991 to January 16, 1992.

Abundance of black spot in commercial vineyards

During season 1992/93 eight commercial Sultana vineyards in the Sunraysia district were inspected fortnightly and the incidence of disease was recorded. The surveys included overhead, furrow and undervine irrigated vineyards. All but one of these vineyards received sprays for black spot control during the growing season.

Results

Infection periods

Season 1991/92

In 1991/92 little spread was observed and only two infection periods occurred (Figure 2). The first was in early September and the second was after flowering. According to the model, other rainfall events did not contribute to infection. A few spots on a few leaves were noted after the first infection period, whilst the second infection period resulted in one or two bunches on some vines with up to 3% of berries diseased.

Season 1992/93

In 1992/93 conditions favoured widespread development of symptoms in unsprayed vineyards. There were at least seven distinct black spot infection periods prior to flowering (Figure 3). After flowering there were also numerous black spot infection periods both before and after berry softening. Some of these were associated with periods of heavy rainfall.

Spread studies

In 1991/92 disease severity varied from 0 to 0.2% of leaf and stem area diseased on inoculated vines. Little spread to neighbouring vines was observed. An inspection for black spot cankers just before budburst in spring 1992, indicated that levels of visible overwintering inoculum were low. The majority of inoculated vines had no cankers, while a small proportion had one to two cankers on one or two year old wood. However, the presence of indistinct lesions on tendrils, petiole scars, bunch or berry fragments and leaf litter that may also act as sources of overwintering inoculum (Mirica 1988, Magarey unpublished data) was not assessed.

On 4 November, 1992, 33% of shoots (Figure 4) and 7.5% of leaves (Figure 4) were diseased on vines with overwintering inoculum. At a distance of 4m from inoculated vines, 2% of shoots (Figure 4) and 0% of leaves were diseased (Figure 5). In the next month, however, the level of black spot in the vineyard increased dramatically. On the inoculated vines the incidence of disease on shoots more than doubled and at a distance of 4m it increased twenty five fold. By berry set, 2% of shoots were infected with black spot 68m from the inoculated vines (Figure 8). The incidence of black spot decreased dramatically when distance from the inoculated vines exceeded 7m, and reached trace levels at and beyond 30m. Similar patterns of spread was also observed in other unsprayed Sultana vineyards.

By 31 December1992, black spot was widespread on all vines, however, berry disease still varied greatly with distance from inoculated vines. Almost 100% of bunches were diseased on inoculated vines and bunch a severity was 30%. At a distance of 4m from inoculated vines almost 70% of bunches had some disease, but only 3.5% of the bunch surface area was diseased (Figure 6).

At harvest, bunch disease severity varied from 17% on some vines to 2.3% on vines 6.8m or more distant (Figure 7). However, even at a distance of 6.8m bunch disease incidence was 70%. Bunch weight was significantly ($P < 0.05$) higher at distances of 3.4m or more and was

almost 3 times greater at 6.8m. There was no significant difference (P = 0.05) in the number of bunches per vine with distance from overwintering inoculum.

Incubation period
Symptoms first appeared as tiny pin size brown coloured lesions which expanded progressively with time. The incubation period of black spot varied from five days at a mean average daily temperature of 21-24°C, to seven days at 14-16°C.

Ascigerous stage
No ascospores were positively identified during spore trapping. Microscopic examination of a collection of cankers on young and old wood and isolates from the Plant Research Institute's Burnley Herbarium failed to reveal the presence of ascomata.

Abundance of black spot
No black spot was observed in seven of the eight commercial Sultana vineyards surveyed. One infected vine with several infected shoots was found in the other. This is an indication of the low incidence of black spot in sprayed commercial vineyards. In the same season black spot caused 100% crop loss in an unsprayed overhead irrigated commercial Sultana vineyard at Loxton, South Australia.

Discussion

The development of epidemics of black spot follows a predictable pattern and is mainly influenced by the presence of overwintering inoculum and the frequency of infection periods. The potential for rapid disease spread is also limited by the low levels of inoculum in sprayed commercial vineyards and low potential for spore dispersal in seasons with unfavourable weather conditions.

The apparent absence of the ascigerous stage from Australia excludes wind blown ascospores as a means of disease spread. Conidia must be splashed by rain or carried by insects to cause new infection. Overwintering cankers appear to only have a viability of 2-5 years (Paufilova 1950, Brook 1992) and standard pruning methods remove most diseased material. In unsprayed vineyards even low levels of overwintering inoculum can cause localised crop loss when conditions are favourable. Prior to flowering, damage was almost exclusively confined to vines with overwintering inoculum or adjacent vines. As favourable conditions continued, vines 10m from inoculated vines developed a high incidence of disease. Severity and incidence of bunch disease were lower at harvest than on 31 December, 1992. This could be due to different methodology or probably because diseased bunches thereof, tend to detach with time. Infection periods after berry softening also do not greatly contribute towards bunch infection because of reduced bunch susceptibility (Brook 1973).

Black spot management in vineyards with infrequent spring rainfall does not require routine spraying, and when overwintering inoculum is absent spraying can be withheld. If black spot inoculum is widespread in a vineyard then early season sprays from budburst until at least flowering should be applied. When frequent periods of wet weather occur after bud burst, the vineyard should be checked for black spot symptoms and sprayed before flowering.

Given the continuation of favourable weather conditions, the onset of crop loss occurs rapidly once the third generation of lesions has appeared. New lesions, however may not become obvious in the vineyard until 10-14 days after an infection period. In seasons with only one or two infection periods before flowering no spraying will be required unless overwintering inoculum levels are high. An infection model relating the number of infection periods to spray need is currently under construction for the AusVit expert system for grapevine management (Travis *et al.* 1992).

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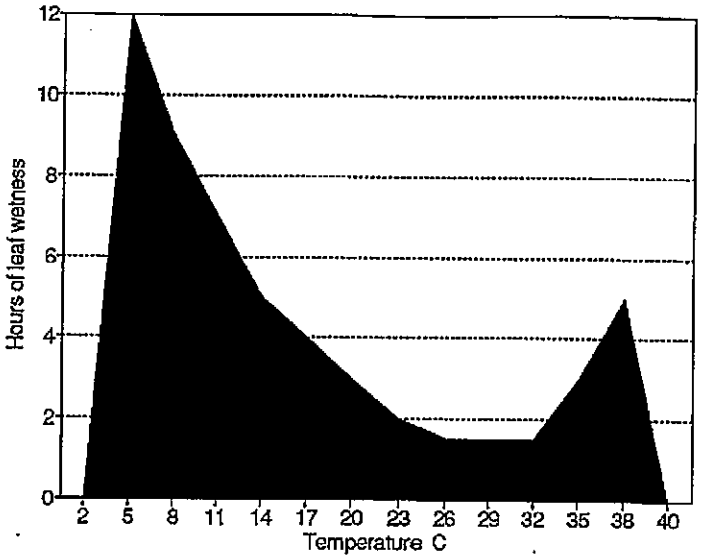


Figure 1. Estimated leaf wetness temperature combinations required for grape foliar infection by black spot caused by *Elsinoe ampelina*.

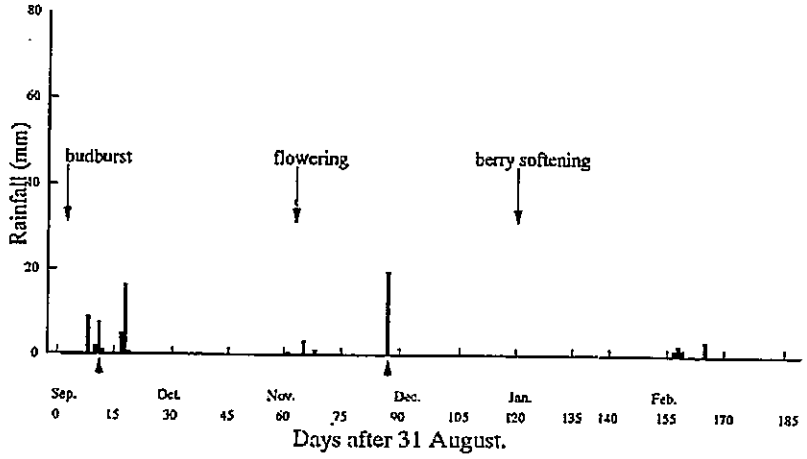


Figure 2. Rainfall at Mildura, Victoria during the 1991/92 growing season. Infection periods for *Elsinoe ampelina* are marked with arrows below the histograms.

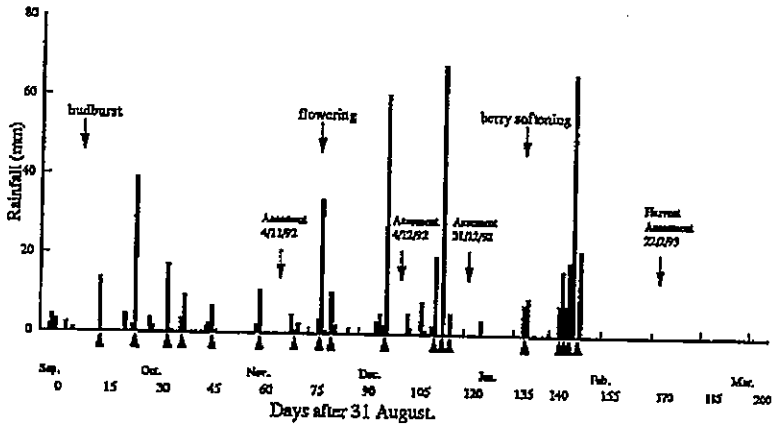


Figure 3. Rainfall at Mildura, Victoria during the 1992/93 growing season. Infection periods for *Elsinoe ampelina* are marked with arrows below the histograms. Dates of assessments of black spot spread are indicated.

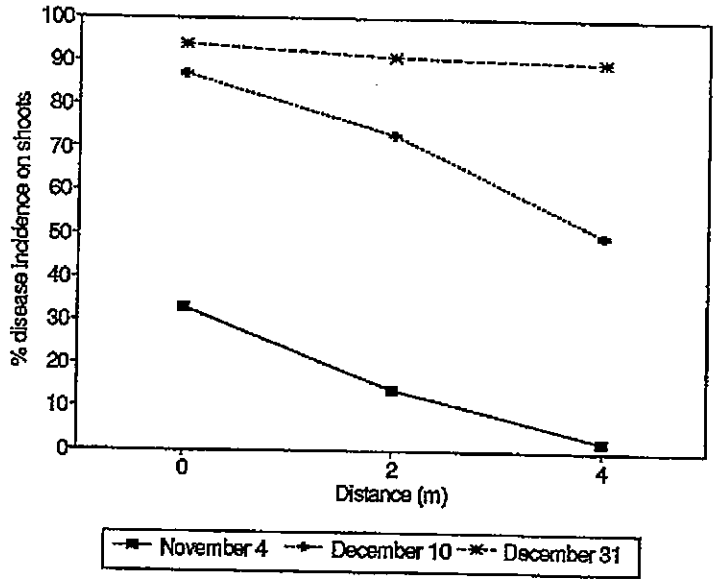


Figure 4. Incidence of black spot on shoots at increasing distances from vines diseased the previous season.

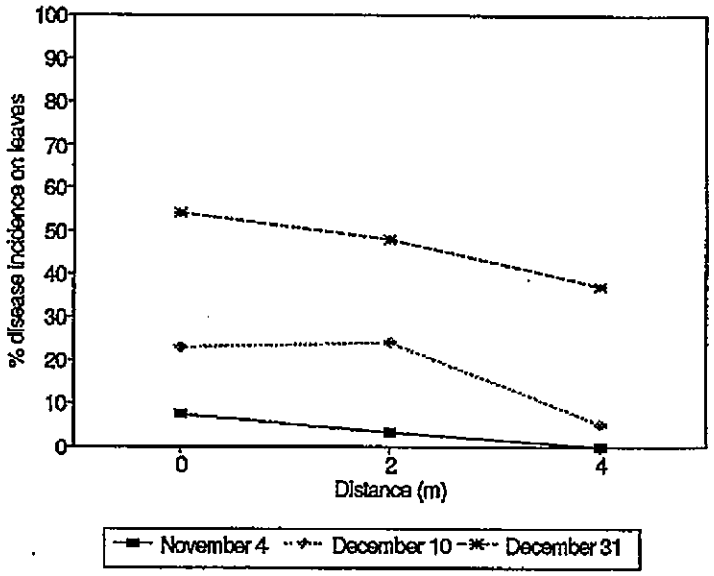


Figure 5. Incidence of black spot on leaves at increasing distances from vines diseased the previous season.

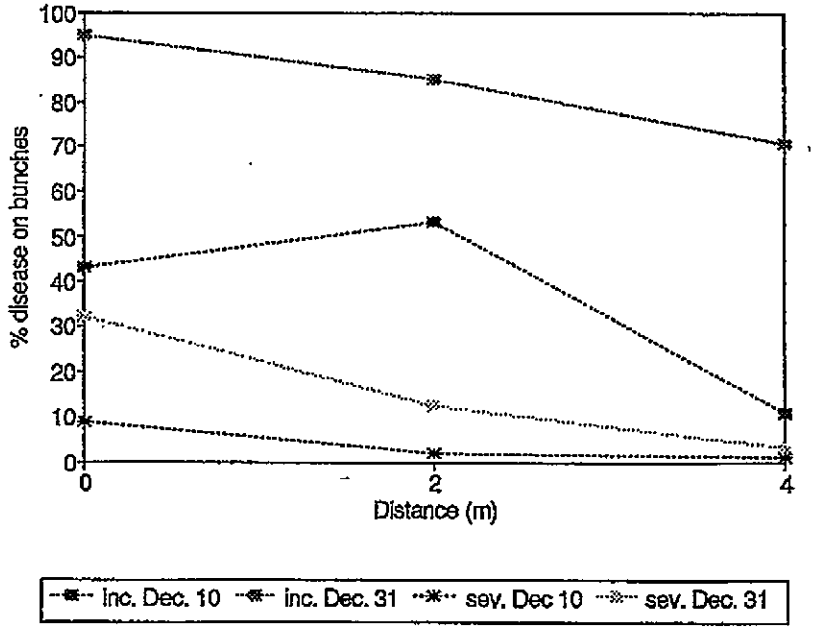


Figure 6. Incidence (% bunches diseased) and severity (% bunch surface area diseased) of black spot at increasing distances from vines diseased the previous season.

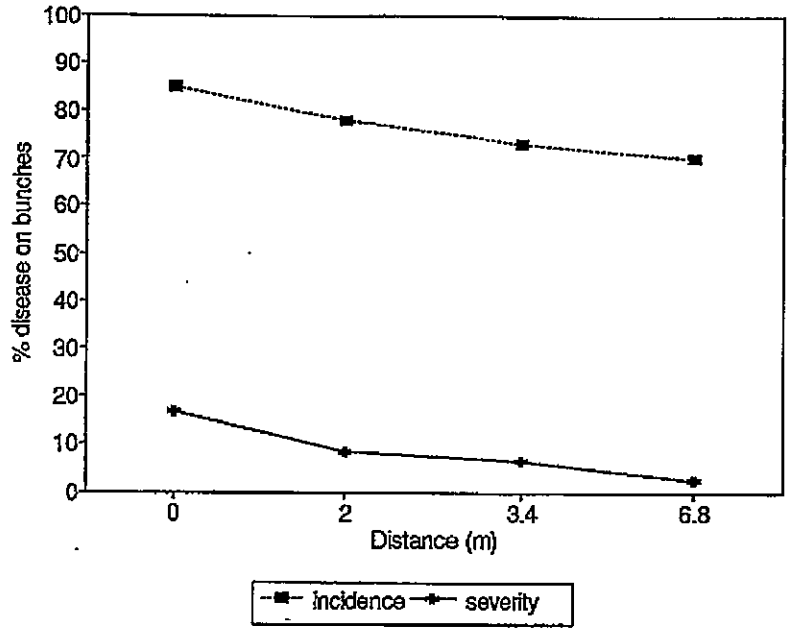


Figure 7. Incidence (% bunches diseased) and severity (% bunch surface area diseased) of black spot at harvest at increasing distances from vines diseased the previous season.

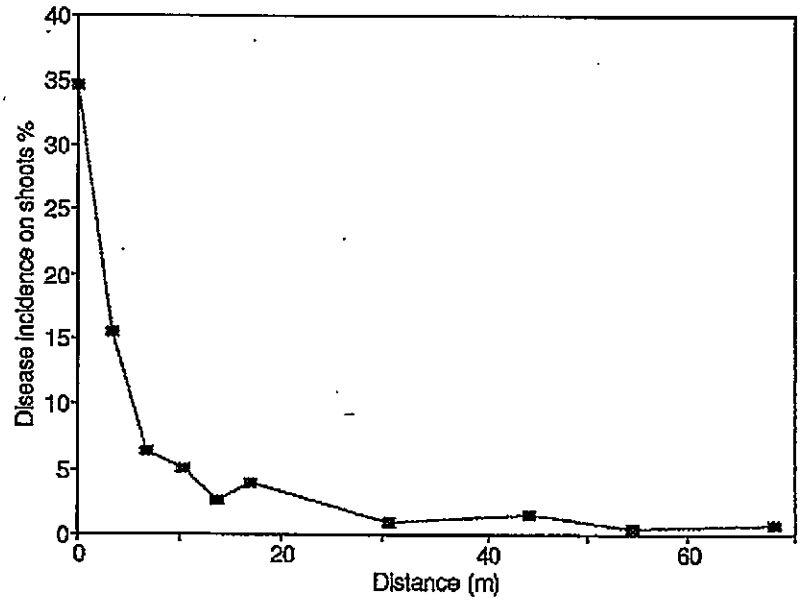


Figure 8. Incidence of black spot after berry set (25 November) at increasing distance from vines diseased in the previous season.

Appendix 5. Susceptibility of grapevine cultivars

a) **Susceptibility of grapevine selections to black spot (anthracnose) *Elsinoe ampelina*.**

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Susceptibility of grapevine selections to black spot (anthracnose) *Elsinoe ampelina.*

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Abstract

One hundred and eighty six *Vitis vinifera* cultivars, other *Vitis* species and hybrids including those used for rootstocks were assessed for susceptibility to grapevine black spot (anthracnose) caused by the fungus, *Elsinoe ampelina.* The study was undertaken in 1992/93 when seasonal conditions were conducive to black spot infection. Vines assessed were part of the "Vine Variety and Rootstock, Wood Production and Species Collections" at Roseworthy Agricultural College, South Australia. Black spot infection had been recorded in previous seasons in these vineyards. Eighty three percent of vines assessed exibited no disease symptoms, while the remainder were diseased to varying degrees. Results of this study are compared with those of other studies in Australia and overseas.

Introduction

Grapevine black spot or anthracnose is caused by the fungus, *Elsinoe ampelina.* In the past, black spot was an important disease of grapevines, causing substantial crop loss. However, incidence of black spot in vineyards has been significantly reduced since the mid-1950's when dithiocarbamate fungicides such as ziram were introduced (Emmett, 1980; Magarey, Coffey and Emmett, 1993). The disease is now considered to be controlled in most commercial vineyards (Emmett, *et al*, 1992), although under optimum conditions, outbreaks still occur. Spray programs are, therefore still required to prevent crop loss, especially on susceptible cultivars such as Sultana.

Apart from optimum weather conditions, disease incidence is largely dependent on the presence of overwintering stem cankers from previous seasons (Emmett, 1980). High humidity or moist conditions encourage dormant overwintering stem cankers to produce conidia (du Plessis, 1940). These water-borne conidia infect actively growing or expanding green vine tissue in the presence of moisture (Emmett, 1980). Symptoms of black spot first appear on green tissue as small, round reddish brown lesions. Infection of more mature vine tissue follows. Infected berries develop black necrotic spots. Severe or heavy

infections may result in substantial crop loss and reduced vine vigour for several seasons (Magarey, Coffey and Emmett, 1993).

Unusually wet, cool conditions in the 1992/93 season were especially conducive to black spot infection.

Methods

Severity of black spot on grapevines was assessed on 21 January 1993 in the "Vine Variety and Rootstock, Wood Production and Species Collections" at Roseworthy Agricultural College, South Australia. The vineyard was irrigated by overhead sprinklers. Black spot control measures were not applied, however, potassium phosphite (Foli-R-fos®, UIM Chemicals (Aust.) Rocklea, Qld), copper and sulphur fungicides were sprayed for downy and powdery mildew control, none of which are effective against black spot (Magarey, Coffey and Emmett, 1993). One hundred and eighty six grapevine selections including fruiting cultivars of *Vitis vinifera*, other *Vitis* species, hybrids and rootstocks were assessed. Each selection consisted of a panel of three mature vines trained on a simple two wire trellis system.

Vines were scored according to the presence or absence of visible infection and then separated into two primary groups: vines with nil or trace disease (1-5 lesions per vine) and vines with more than a trace of disease. The latter group were reassessed and scored for disease severity. Five shoots, leaves and bunches were scored on all three vines in each panel, giving a total of 3 x 15 scores per selection. Bunches were sparse or absent on some vines, so the final result was based on shoot and stem scores only. Scores were nil (0%), light (>0 - <1.0%), moderate (1.0 - 5.0%) and severe (>5.0%) assessed on the basis of percentage surface area diseased using diagrammatic keys. Average severity scores were tabulated, as an indication of each selection's susceptibility to black spot.

Results

Vines severely diseased with black spot were randomly scattered throughout the vineyard. Disease severity recorded on the grapevine selections assessed is summarised in Table 1. Overall, 83% of selections exhibited no disease symptoms, 8% were lightly diseased, 4.5% were moderately diseased and 4.5% were severely diseased (Figure 1.). The *Vitis vinifera* cultivars Calmeria and Tullilah had the highest disease scores of 32% and 40% respectively. Sultana was also severely diseased with a severity score of 11%.

No symptoms of black spot were observed on the other *Vitis* species, hybrids and rootstocks (Table 2.).

Discussion

The results of this assessment highlight the variation in susceptibility to black spot of *Vitis vinifera* cultivars. Comparable assessments have been reported by Jennings (1950), Mortensen (1981), and Yadav and Nirwan (1980), as reviewed by Magarey and Emmett (1993), although there were several inconsistencies. Jennings (1950) rated Palomino,

Grenache and Semillon as "heavily infected" and Mortensen (1981) rated Cardinal as exibiting "severe symptoms", while these cultivars were not diseased in our assessment. Cabernet Sauvignon was rated as exibiting severe symptoms by Mortensen (1981), however, this cultivar showed no symptoms in our assessment and was also rated by Jennings (1950) as "not infected". Some cultivars such as Doradillo and Zante Currant were recorded by Jennings (1950) as exibiting slightly higher levels of disease than in our assessment.

Discrepancies between the reports cited may be explained by several factors including differences in monitoring techniques, grapevine age, inoculum intensity, fungal strains and seasonal conditions. Type of irrigation system, vine position and spacing, and trellis systems may also have an influence because of their effect on vine microclimate.

Cultivars considered to be highly susceptible, such as Sultana and Black Monukka were rated as severely diseased in our assessment, in agreement with the "heavy infection" or "very severe symptoms" rating given in papers reviewed by Magarey and Emmett (1993).

Factors such as vine vigour may play an important role in grapevine susceptibility to black spot. An extended period of growth may increase the amount of young vine tissue which is susceptible to infection and hence increase the probability of higher disease severity.

The majority of wine grape cultivars and rootstock selections assessed showed no signs of disease and appear, therefore, to be resistant to infection by *Elsinoe ampelina*.

Acknowledgments

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Table 1. Black spot severity on grapevine selections at Roseworthy, SA (Jan. 1993).

*Nil 0%	+Berry Colour	=End Use	Nil 0%	Berry Colour	End Use	Light <1.0%	Berry Colour	End Use	Moderate 1.0-5.0%	Berry Colour	End Use	Severe >5.0%	Berry Colour	End Use
Aleatico	b	W	Merlot	b	W	Black Frontignac	w	W	Almeria	w	T	Black Monukka	b	T
Aramon	b	W	Mondeuse	r	W	Carignan	w	W	Canner	W	P	Calmeria	w	T
Aszarro			Morrils	w	W	Dorsalillo	b	T	Carina Currant	b	D	Emerald Seedless	w	T
Baco Noir No.1	w	W	Muscadelle	w	W	Exotic	r	T	Delight	w	T	Goyura	w	W
Barbera	b	W	Nebbiola Bourgo	r	W	Flame Tokay	r	T	Parana	w	W	Olivette Noir	b	W
Barlinka	b	T	Ondenc	w	W	Kishmishi	r	T	Hepatakilo	w	W	Red Malaga	r	T
Bastardo	b	W	Palomino	w	W	Muscat Hamburg	b	T	Muscat Gordo	w	W,T,D	Sultana H5	w	W,T,D
Bizzano	w	W	Parellada	w	W	Nyora	r	W	Perlette	w	T	TallRah	w	W
Bonvedro	b	W	Perla de Csaba	w	T	Red Frontignac	b	T	Thomascot	w	T			
Cabernet Franc	b	W	Petit Verdot	r	W	Ribier	r	T						
Cabernet Sauvignon	b	W	Pinot Gris	g	W	Ruby Seedless	r	T						
Canada Muscat	w	W,P	Pinot Meunier	r	W	Sabelkan-Skol	r	W						
Cannon Hall Muscat	w	T	Pinot Noir	b	W	Sangiovese	b	W						
Canocazo	w	W	Pinot Noir (D-5)	b	W	Sarmoll	w	W,T,D						
Cardinal	r	T	Prokupac	b	W	Waltham cross	w	W						
Catawba	r	W	Queen	w	T	White Frontignac	b	W						
Chardonnay	w	W	Raberer	w	W									
Chasselas Cioutat	w	W,T	Red Lady's Finger	r	T									
Chenin Blanc	w	W	Riesling	w	W									
Cinsaut	b	W	Riesbeo Piavo	b	W									
Colombard	w	W	Rizziteli	w	W									
Concord	b	W,P	Rousanne IC7408289	w	W									
Criolla Negra	b	W	Royal Ascot	b	T									
Crouchen	w	W	Rubired	b	W									
Dechaunac	r	W	Ruby Cabernet	b	W									
Delaware	r	W	Saperavi	b	W									
Dourado	w	W	Sauvignon Blanc	w	W									
Durif	b	W	Semillon	w	W									
Early Muscat IC68-8027	w	T	Shiraz	b	W									
Emperor	r	T	Smederevka	w	W									
Ficus	w	T	Sonora	r	W									
Flame Seedless	r	T	St Macaire	r	W									
Poch IC72-8198	r	W	Sylvaner	w	W									
Purmint	w	W	Taminga	w	W									
Gamay (HT 120-B)	r	W	Tamar	r	W									
Gold	w	T	Tarrango	b	W									
Gree Rosso (Bermestia)	r	W	Tinta Cao	r	W									
Grenache	b	W	Tinta Molle	r	W									
Grey Grenache	g	W	Touriga	r	W									
Harslevela	w	W	Traminer	w	W									
Italia	w	T	Traminer x Riesling	w	W									
Kadarka	b	W	Trebbiano	w	W									
Kyoho	r	T	Valdiguie	r	W									
Maccabeu	w	W	Verdelho	w	W									
Malbec	b	W	Villard Blanc	w	W									
Malvasia Bianca	w	W	Voigner	w	W									
Marmolo	b	W	Zante Currant	b	D									
Marsanne	w	W	Zinfandel	b	W									
Matero	b	W												
Melon	w	W												

NOTES:
* Field description and % area diseased.
+Berry Colour: b=black, r=red, w=white, g=grey.
=End Use: W=Winemaking, T=Tablegrape, D=Drying grape, P=Processing (juice, etc).

Table 2. Grapevine rootstocks, hybrids and other species exhibiting no black spot symptoms in vineyards at Roseworthy, S.A. (Jan. 1993)

101-14	Aurora 8180	J 12-48	Romulus 2241
106-8	AXR 1 (ARG #1)	JA 69	Rupestris du lot
1202	*Barthenocissus quinuefolia*	Jacquez	Seneca IC69-8113
125 AA	Cayuga White	K 51-32	SO 4
140 Ru (140 Ruggeri)	*Cissus rhombifolia*	K 51-40	Schwarzmann
16-13	Curderc Noir	Mtsvane 8283	Teleki 5A
16-16	Dog Ridge	Ortrugo	Teleki 5C
161-49	Early Greek	P 1103 (1103 Paulsen)	Valensi Blanc
3306 C	Elvira IC70-8155	*Parthenocissu tricuspidata*	Venus
34 EM	Folle Blanche	R 110 (110 Richter)	Verdelet IC69-8077
41 B	Freedom	R 99 (99 Richter)	Villard Noir 8225
420 A	Glenora	Ramsey	*Vitis candicans*
5 BB (Kober 5BB)	Harmony	Riparia Gloire	*Vitis rotundifolia*
Americano	Himrod 8172	Rolle	

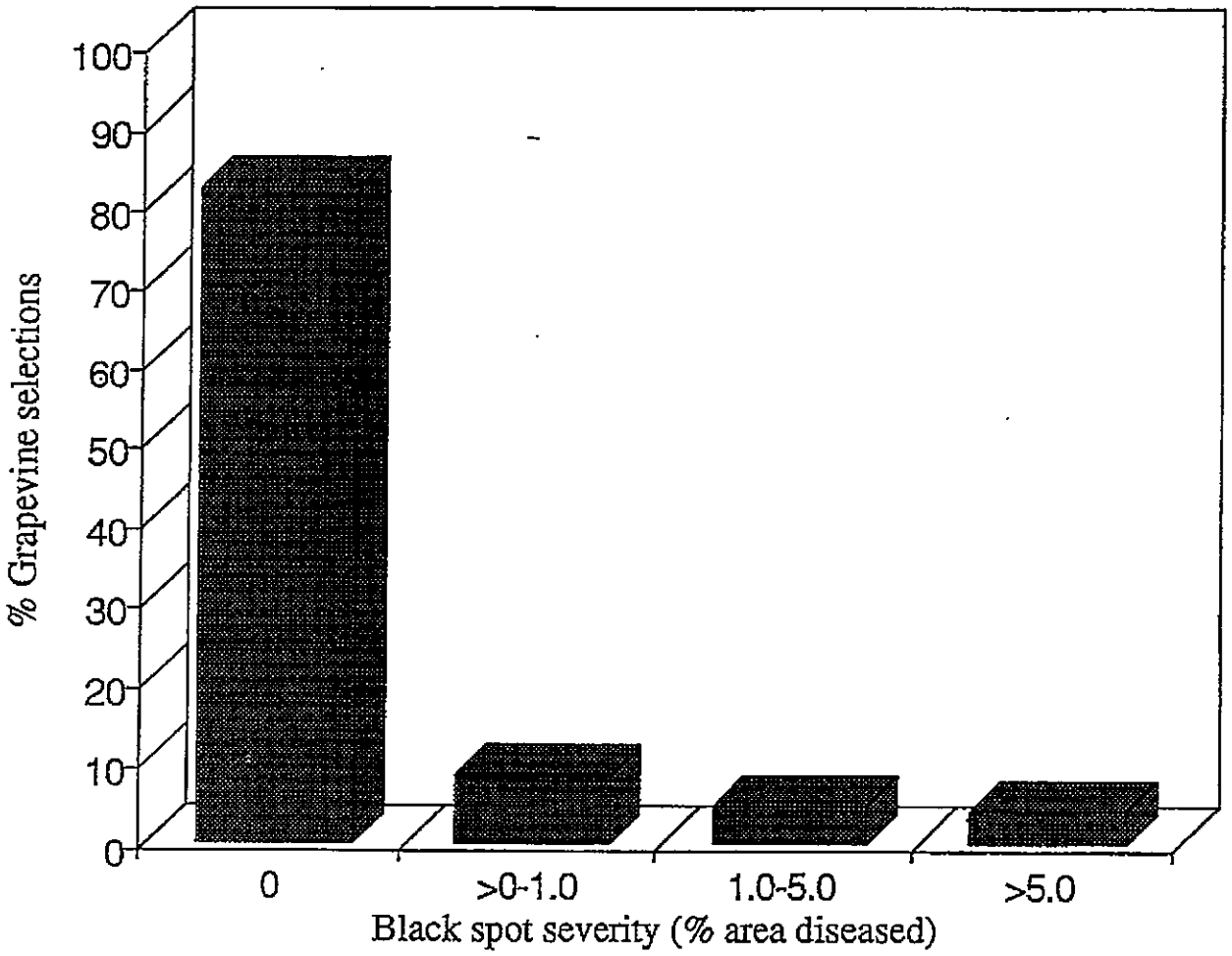


Figure 1. Percentage of grapevine selections recorded in each black spot severity category in vineyards at Roseworthy, S.A. in January, 1993.

Appendix 6 Black spot extension publications

a) **Black spot of grapevines**

B. E. Coffey and R. W. Emmett

Paper published in Aust. Grapegrower & Winemaker No. 321:25-26 (1990).

b) **Black spot of grapes**

R. D. Magarey, R. W. Emmett and P.A. Magarey

Advisory leaflet

c) **Black spot rock**

Draft of potential advisory jingle

d) **"On the land" script**

Script of 2 minute television production.

e) **Horticulture Hotline**

Transcript of recorded advisory message - *9 October 1992*

f) **Cropwatch Newsletter**

Fortnightly industry newsletter - *1 September 1992*

Black spot of grapevines

Brian Coffey and Bob Emmett

Sunraysia Horticultural Centre
PO Box 905, Mildura, Victoria 3502.

Black spot disease, caused by the fungus *Elsinoe ampelina*, is also known as anthracnose or bird's eye spot of grapevines. References to the disease date back to the days of ancient Rome, making it one of the oldest known diseases of plants.

Disease occurrence and importance

Black spot appears to have originated in Europe (Shear 1929) but is now present in most grapegrowing regions of the world.

Past outbreaks of the disease in Australia have caused serious crop losses in Sunraysia, the Riverland, and the Murrumbidgee Irrigation Area (MIA) as well as other regions. However, since the introduction of dithiocarbamate fungicides such as ziram and thiram in the 1950s (Taylor 1954; Coombe 1953) the severity and occurrence of black spot has declined dramatically. So much so that many growers are no longer concerned about its effect on production.

Nevertheless, serious crop losses may still occur during a series of wet springs if control measures are not applied.



• Black spot: cane cankers and leaf spots.

Symptoms

On leaves, first signs of disease are small light coloured haloes. Soon after, these turn brown, increase in size, and develop a reddish margin. On older leaves the centre of spots becomes dry and ash coloured and with time tears away leaving the leaf with a characteristic "shot holed" appearance.

Black spot symptoms on petioles, shoots and tendrils begin as tiny dark brown spots. These rapidly darken, increase in size and elongate. The margins of the lesions become raised and black while the centres become sunken and ash coloured. Older lesions (cankers) may be pitted or appear charred. Sometimes shoots, petioles or tendrils are killed when they are girdled by cankers.

Infected berries develop round purple-black spots that increase in size with berry growth. The centres of these crusty tar-like spots become pinkish-white when conditions favour sporulation. Severe crop losses can occur if bunch stems are girdled and killed.

Varieties affected

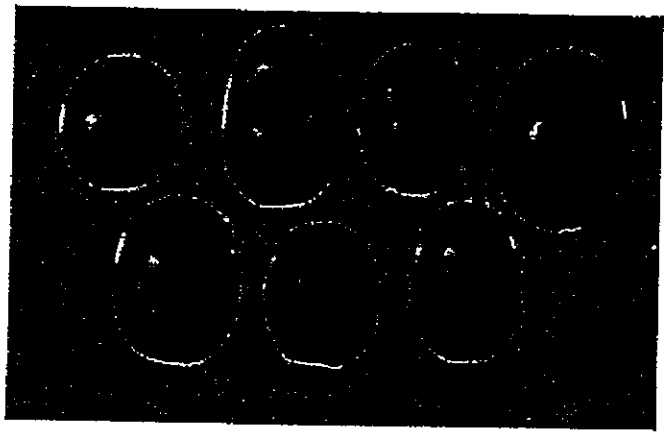
Varieties differ in susceptibility to black spot. Sultanas are highly susceptible. Table grape varieties such as Muscat Hamburg, Waltham Cross, and Ohanez are less susceptible while most wine grape varieties are relatively resistant.

Biology and epidemiology

Elsinoe ampelina survives the winter in structures known as sclerotia which are formed from late summer through to winter as plant tissues harden (Du Plessis 1940).

Overwintering usually occurs within cankers on spurs or unpruned canes although the fungus may also survive on prunings or fallen leaves and berries (Suhag and Grover 1972). *E.ampelina* may persist within infected canes on vines for three to five years (Panfilova 1950).

In spring, overwintering sclerotia within cankers produce numerous spores when set for 24 hours or more at temperatures above 2°C. Subsequently, spores are dispersed onto young vine foliage during rains or overhead irrigations of 2mm or more and infection occurs when green tissues are wet for at least three to 12 hours depending on the temperature. Spores germinate and infect at 2-32°C. The period of incubation (i.e. the period between infection and disease appearance) varies from 13 days at 2°C to three to four days at 21-32°C. Optimum temperatures for disease development are 24-26°C (Brook 1973; Mirica 1988).



• Black spot on mature sultana berries.

As *E.ampelina* is dispersed in water droplets, black spot is a slower spreading disease than downy mildew or powdery mildew. The latter two diseases are mostly spread by wind after primary infection.

Young tissue is most susceptible to infection. As tissues age they become resistant (Brook 1973; Suhag and Grover 1977). Similarly when berries reach a soluble solids content of 5-7% they become highly resistant to infection (Brook 1977).

In districts with low summer rainfall, the likelihood of disease spread declines from late spring onwards each season as

temperatures increase and the incidence of rainfall and the availability of young susceptible tissue for infection decreases. In late summer, overwintering sclerotia are formed particularly in cankers on infected canes.

Control

Because young tissue is most susceptible to infection and is most abundant early in the season, it is important that chemical control programmes begin at budburst.

In the past, drastic measures such as the swabbing of dormant vines with sulphuric acid were recommended for black spot control (De Castella and Brittlebank 1918). Dormant sprays of copper sulphate, lime sulphur or Bordeaux mixture were also prescribed although these were not considered to be as effective as swabbing (Manuel 1928). During the growing season high rates of Bordeaux mixture were often sprayed to enhance control.

Nowadays these treatments are no longer used because of the high labour costs involved, the hazards associated with their application and the availability of more effective treatments that are easier to apply.

Fungicides currently used for black spot control include ziram (Ziram®, Fulasin®), thiram (Thiram®), mancozeb (Dithane M45®, Mancozeb®, Nemispor®) or metiram (Polyram 2000®). Dithianon (Delan®), is used where the control of Phomopsis cane and leaf spot is also required. In most routine spray schedules, these fungicides are applied at fortnightly intervals from 50% budburst to post-flowering. Pre-flowering sprays, particularly those from budburst to four weeks after budburst are most important to prevent the loss of young shoots and flower clusters. From four weeks after budburst onwards, fungicides such as mancozeb, metiram and dithianon that control downy mildew as well as black spot are most widely used in spray programmes.

Current research

There is little doubt that in future years, the range of fungicides available for use in viticulture is likely to change as a result of reviews of their acceptability, particularly by environmental and health agencies. Some of the reasons for the withdrawal of fungicides include new evidence of unacceptable toxicology, inadequate toxicological data following the introduction of more extensive toxicological criteria where it is not worthwhile for agrochemical companies to generate supplementary data in support of re-registration (particularly with respect to old fungicides out of patent), and the loss of efficacy because of the widespread development of fungicide resistant strains (Emmett 1990).

As the use of some dithiocarbamate fungicides in horticulture is under review at present, there is a possibility that some of the fungicides currently used for the control of grapevine black spot may be withdrawn in the near future. This prospect, along with the need to improve the overall efficiency of disease management in Australian viticulture has prompted further research on grapevine black spot at the Sunraysia Horticultural Centre, Irymple, Victoria. The current research programme is jointly funded by the Dried Fruits and Grape and Wine Research Councils. It involves fungicide screening trials to find alternatives to the dithiocarbamates and biological studies to explore new approaches to black spot management in vineyards (Emmett *et al* 1990).

In preliminary screening tests, a range of fungicides that are already used for the control of other diseases of grapevines such as powdery mildew (e.g. fenarimol and sulphur), downy mildew (e.g. chlorothalonil) and *Botrytis* (e.g. benomyl) along with some other fungicides (e.g. prochloraz) were tested for their effects on black spot development. In relation to ziram and mancozeb, the fungicides most widely used for black spot control in vineyards at present, fenarimol, chlorothalonil and benomyl provided similar disease control. Prochloraz was most effective in reducing disease incidence while sulphur was least effective. Fenarimol and prochloraz, however, caused some phytotoxic effects on young vine growth during glasshouse tests.

Further research on fungicide efficacy and alternative approaches to black spot control will be conducted during 1990/91 and 1991/92.

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BLACK SPOT OF GRAPES

by Roger Magarey*, Bob Emmett & Peter Magarey
*Sunraysia Horticultural Centre, P.O. Box 905, Mildura, Victoria, 3502

How it starts: WET SEPTEMBER*

- The disease survives the winter as cankers on canes or prunings on the ground. Some vineyards have little or no resident disease.
- The disease spreads during rainfall or overhead irrigation of 2mm or more when leaves are wet for at least 6 hours. *Frequent periods of rainfall in the first month after bud burst is critical.
- Only certain cultivars (e.g. Sultana) are susceptible. Most wine cultivars are resistant.

Wet September
Please remember



Black spot
Can hit the crop

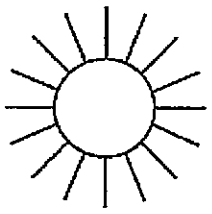
Result: BLACK SPOTS

All green plant tissue can get them. The edges of the lesions are raised and black whilst the centres are slightly sunken and ash coloured. Symptoms are easily visible 10-14 days after infection.

The Spread: CONTINUING WET WEATHER

- After spots have appeared, follow up rains will spread disease (secondary infection). Regular rainfall causes frequent secondary infection.
- Developing bunches are **highly susceptible** until berry set, although berries continue to be infected until they soften.
- Foliage susceptibility is low from flowering onwards.

Dry September
Dry October



Black spot problem
it's all over

Result: CROP LOSS

By flowering severe crop loss can occur on any vines that had black spot the previous season. Bunches can be totally destroyed whilst canes can be girdled and killed by large cankers, causing long term yield reductions in following seasons.

Control - EARLY SEASON SPRAYS;

but only when needed

Black spot in any of the previous two seasons / wet climate

Spray at budburst and two weeks later. Continue fortnightly until flowering if wet weather occurs.

Black spot absent in previous two seasons

Do nothing until first secondary infection period and then apply a protectant at fortnightly intervals until flowering. Remember overhead irrigation may also cause infection. Alternatively check the vineyard regularly and begin a spray program if black spot is seen.

After flowering

Spraying for black spot after flowering is not required unless the disease is present on more than 10% of shoots. Some downy mildew fungicides will also control black spot.

Black spot rock

By Roger[a] and Peter[b] Magarey

[a]Sunraysia Horticultural Centre,
P.O. Box 905, Mildura, 3500.
[b]Loxton Research Centre,
P.O. Box 411, Loxton, 5333.

Wet September please remember
Black spot can hit the crop
Dry September there is no worry
Save your sprayer save your money

Black spot won't make you cry
When the weather stays so dry

If you had black spot last year
Listen up and listen clear
Prevention pays and is good reason
Get those sprays on early season

Black spot won't make you cry
When the weather stays so dry

Overhead irrigation and rain
Both make leaves wet just the same
Disease will spread in rainfall showers
when its wet for six straight hours

Black spot won't make you cry
When the weather stays so dry

Early season control is important
Ziram is the one most potent
Combine it in a spray for powdery mildew
For spot at bud burst and both at week two

Dry September Dry October
Black spot danger it's all over
But when it's wet be sure to check
Black spot may get going yet

Black spot won't make you cry
When the weather stays so dry

Wet September please remember
Black spot can hit the crop
by November there is no worry
Save your sprayer save your money

"On the Land" script

Script for 2.30 min television production.
Produced by the Sunraysia Horticultural Centre Video Unit.

O.T.L Black spot control
Roger Magarey
Dur. 2.30 min
Air date: 4/9/92

Grapevine black spot is a disease which has the potential to totally devastate Sunraysia's grapevine crops. In particular the Sultana variety, is very susceptible to the disease. Outbreaks of black spot are, however, highly infrequent and are closely related to the incidence of spring rainfall.

The disease overwinters as cankers on canes and can survive for several years even if conditions are unfavourable for it's spread.

Under normal conditions the fungus that causes black spot requires at least 5-6 hours of leaf wetness to infect grapevine tissue. Because only actively growing tissue is infected the period of greatest risk is from bud burst to flowering.

As a result the disease is usually only a problem when frequent periods of rainfall occur in September or October.

About two weeks after an infection period the symptoms of the disease become visible. Small black spots will appear on any green part of the plant, including leaves, stems and berries. These black spots can grow into larger cankers which severely weaken the stems and may eventually kill the canes.

An annual program for black spot control isn't usually required, however if you have overhead irrigation or heavy soils you'll need to be more vigilant.

With black spot prevention is better than cure. So if you think black spot is a potential problem in your vineyard early season control is important.

A suitable pre-infection or protectant fungicide registered for black spot should be applied at budburst and at two weeks after budburst. This will protect new growth and prevent the spread of the disease.

To find out if conditions have been suitable for black spot disease you can ring the Horticulture Hotline on 514 560. This service also includes information on the activity of a whole range of pests and diseases as the season progresses.

Horticulture Hotline: 9 October 1992

Welcome to Horticulture Hotline, sponsored by Vineleaf Stores. This week's messages are about black spot, powdery mildew, downy mildew, and snails. The message was compiled on Friday 9 October, and will be updated on Tuesday 13 October.

Downy mildew primary infection mostly occurs during rains of at least 9-10 mm, when temperatures are 10°C or more and soils are wet for at least 24 hours. In vineyards being monitored in the Irymple area, there was a high risk of downy mildew primary infection during rains on the 8th and 9th of October. Because of this growers with vines that have experienced conditions for primary infection are advised that if a spray for downy mildew control has not been applied within the last 7-10 days, a post infection or eradicant fungicide should be applied before Friday the 16th of October. If this cannot be achieved, a suitable pre-infection or protectant fungicide for downy mildew control such as copper oxychloride or mancozeb should be applied as soon as possible. The latter sprays however, will not prevent the appearance of downy mildew oil spots if infection has occurred but they will reduce spread of the disease to new foliage after the appearance of oil spots.

A high level of black spot has been observed in unsprayed vineyards resulting from infections during rains on the 15th, 22nd and 24th of September. Further infections caused by rains on the 8th and 9th of October are likely to appear after the 21st. All vineyards with susceptible cultivars should be sprayed regularly from now until berry set, especially if the weather remains wet. Downy mildew fungicides containing mancozeb, metiram or dithianon will also provide protection against black spot. Dithianon will also provide protection against Phomopsis.

Widespread infections of powdery mildew have been observed in some vineyards where the disease has carried-over from last season. Occasional shoots infected with powdery mildew that have developed from infected buds are already producing wind-blown spores that can spread the disease. Leaf spots resulting from infections by overwintering spores released from cleistothecia (tiny overwintering structures of the powdery mildew fungus that harbour on vine bark and leaf litter) have also been observed in some vineyards. These infections occurred during rains between the 15th and 24th of September that exceeded 2.5 mm when temperatures were 10°C or more. Vineyards, especially those with a recent history of powdery mildew should be checked each week for disease symptoms from this week onwards. If a spray for powdery mildew control has not been applied within the last week or so, spray vines with wettable sulphur or another suitable fungicide this week. For protection against powdery mildew, apply sprays at 2, 4, 6 and 10 weeks after budburst.

Snail numbers are increasing in monitored vineyards as the wet spring conditions continue. Both brown garden snails and white snails are actively moving on and off vines and are beginning to breed. If baits have not already been applied, apply methiocarb or metaldehyde baits immediately to the base of each vine. This will significantly reduce the number of breeding snails.

Check for snail activity even in vineyards or parts of the vineyard that have not previously had snail problems. Baits softened by 3-4 light rains are still proving to be effective.

Copper sprays applied for downy mildew control will help repel snails from vine foliage, and increase the number exposed to the baits.

In summary,

- spray vines for downy mildew control
- vines susceptible to black spot should be sprayed regularly
- powdery mildew has already been seen in some vineyards; ensure protective sprays are applied
- check for snails and bait as necessary.

Thank you for calling Vineleaf Stores Horticulture Hotline.

CROP WATCH PTY. LTD.
Incorporated in Victoria
Phone: (050) 24 5603
P.O. Box 905,
Mildura, Vic., 3502.

Cropwatch Newsletter

No. 1 - 1/9/92

Key pest and disease information

Snails - check for snails in cover crops or weeds. If necessary, apply methiocarb or metaldehyde baits at the base of vines.

Mites - apply lime sulphur at advanced woolly bud stage and/or wettable sulphur at 2 weeks after budburst

Black spot - apply a fungicide spray at budburst and another 2 weeks after budburst.

Welcome to another season of Cropwatch Newsletters and Horticulture Hotline telephone messages, courtesy of the Irymple Group of Companies. We will try to keep you informed of seasonal pest and disease problems, and offer practical and useful advice on pest and disease management.

The Cropwatch Newsletter will be posted to you twice a month, to reach you about the 15th and the end of each month. The mailing list is managed by the Irymple Group, so please contact them on:

Ph. 24 5704, or PO Box 19, Irymple, 3498
to change or update your address.



The Horticulture Hotline has a new number in Mildura, which is (050) 514560. The Robinvale number is still the same, (050) 264568. We suggest that you use the Hotline to keep up to date with pests and diseases, as well as reading the newsletter. The Hotline has the advantage of information being current (to the week), although the information is not as detailed as in the newsletter. The two services should complement each other.

Thanks to all those growers who responded to the questionnaire at the end of the last season. The comments and suggestions were very useful. A summary of the responses follows later in the newsletter, for your interest. ☐

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Snails



Snails generally reproduce in autumn, and the young snails develop during the cool wet winter months. If you have not already done so, it's worth checking cover crops, weeds, and vines for snails. Those growers who did not apply snail baits in autumn or during winter may find too many snails in their block. If so, it would be a good idea to apply baits within the next few weeks, while the snails are still active and before they enter a summer dormancy.

Snails are generally active at night, or on humid overcast days. During dry periods, they seal themselves onto a hard surface. They remain dormant during summer, at least until free water or high humidity dissolves the hard mucous used to seal the opening of the shell.

Baits containing metaldehyde or methiocarb attract and kill the snails, provided they are present while snails are active. Check the labels about application rates,

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VINELEAF STORES
At Each Location

and note that methiocarb baits are also attractive, and **lethal, to dogs.**

Metaldehyde baits paralyse the snails, which then die due to water loss (or other poisons which may be mixed with the metaldehyde). Methiocarb baits affect the nervous system of snails, in the same manner as other carbamate and organophosphate insecticides..

Snails can be repelled from vines with copper-based fungicides. Sprays of copper oxychloride (or other forms of copper) applied to foliage from October onwards, for control of downy mildew will aid in reducing snail problems, provided the snails are active at or soon after the spray application.

Snails can cause considerable damage to vines, by moving onto vines after the ground is cultivated. Young shoots and bunch primordia will be eaten by the snails, and any snails remaining on the vines at harvest may contaminate the crop. Spring is the best time to control snails, with baits at the base of vines. □

Mites



Mites on grapevines in Sunraysia do not usually cause significant crop loss, with the exception of bunch mite on table grapes, and they are relatively easily controlled with "safe" miticides (e.g. sulphur).

The mite pests on grapevines in Sunraysia are bud mite, blister mite, rust mite, and bunch mite.

Bud mite can cause bud failure, or death of shoot tips, or abscission of bunch primordia in early spring. The mite seldom causes economic damage in sultana or gordo, and can be countered by leaving a few extra buds per vine.

Grapeleaf blister mite (erinose mite) causes blisters on the leaves which can lead to reduced shoot growth and sunburn. The blisters do not affect photosynthesis until at least half of the leaf is affected. Blister mites are only important on young vines or susceptible varieties such as gordo.

Grapeleaf rust mite lives freely on the leaf surface, feeding on epidermal cells, eventually causing dark scarring of the leaf.

Bunch mite - causes black scarring on the base of shoots and bunch and berry stems and is sometimes thought to contribute to berry shatter at harvest.

Predatory mites, *Amblyseius victoriensis* (or "Victoria"), *Amblyseius loxtoni* (perhaps "Loxy"), and *Typhlodromus doreenae* ("Doreen") are now known to be important in control of blister, rust, and bunch mites in Sunraysia-Riverland, thanks to research by Dr David James at Yanco. The predatory mites are very efficient in control of blister mites, but bunch mite can still be a problem.

The synthetic pesticides and fungicides applied to grapevines can affect biological control of mites. While there is much to be learnt about the effects of different pesticides, it does appear that spray programs using copper, sulphur, and *Bacillus thuringiensis* are relatively harmless to the predatory mites. So, grapegrowers wishing to minimise chemical use should try to encourage biological control of pest mites by "Victoria", "Loxy", and "Doreen", which in turn means using simple protectant fungicides.

The main mite problem in Sunraysia is bunch mite, especially on table grapes. Fortunately, bunch mite can be easily controlled by wettable sulphur sprays. A spray program of wettable sulphur at 2, 4, 6 and 10 weeks after budburst should give good control of bunch mite and other grapevine mites, as well as powdery mildew.

Some growers may wish to use the traditional lime sulphur spray, which should be applied at the advanced woolly bud stage. Alternatively, there are other registered treatments for mite control, which are listed on the Vine Pest and Disease Control Chart.

This season, we will be emphasising early season control of pests and diseases. Early season control ensures good spray coverage, it should provide more eficient control of pest or disease populations, and will minimise the risk of pesticide residues in your crops.□

Black spot

Grapevine black spot is a disease which has the potential to cause total devastation of crops, particularly on susceptible varieties such as Sultana. Outbreaks of the disease are however, highly infrequent, and are closely related to the incidence of spring rainfall. Under normal conditions the fungus that causes black spot requires at least 5-6 hours of leaf wetness to infect grapevine tissue. As a result the disease is usually a problem when protracted rainfall occurs in September or October. Symptoms of the disease are black spots on leaves, stems and berries which first appear approximately 7-8 days after an infection period. Lesions on stems can weaken and kill canes.

Control of the disease is usually easily accomplished under Sunraysia conditions. A suitable pre-infection fungicide (e.g. ziram, mancozeb, thiram or metiram) should be applied at budburst and two weeks after budburst, when shoots are about 10cm long. An annual program for black spot is usually not required unless the block has a history of the disease within the

last 3-5 years. Growers with overhead irrigation or heavy soils also need to be more vigilant.

Growers who choose not to apply control treatments for black spot should check their vineyards for the disease about 10-14 days after an infection period. Consult the Horticulture Hotline for information about the occurrence of infection periods. □

Results of the Cropwatch client survey

If you recall the survey that was posted out in the mid April issue last season, we asked several questions about the information contained in the newsletter and the style of presentation.

We received about 280 survey forms, which we regarded as a good response rate. However, we would like even more growers to respond next year.—

Generally, growers thought the Cropwatch Newsletter was a good source of information on pest and disease control.

Most growers (70%) ranked it as very important, kept it for future reference (81%), followed its recommendations in their spray programs (70%), and easily understood the information presented (95%).

Growers requested no change (79%) or more detailed information (13%) in the next season's newsletter.

The most useful items in the Newsletter are sections on key pest and disease information (48%), and information on timing of sprays (30%). This may be interpreted as knowing whether or not to spray, and if so, when.

Timeliness of the technical information presented is a crucial issue.

Growers regard Government services, other growers, packing sheds, and field days, as very important sources of information on pest and disease control. The relative value of different sources of information (in relation to pest and disease control) is ranked below according to the proportion of growers classing them as "very important".

Source	*% as "very important"*
Cropwatch Newsletter	70
Vine pest and disease control chart	61
Consultants - Dept. Agric., CSIRO	47
Herbicide book and wall chart	40
Other growers	39
Packing shed	37
Field days and seminars	36
Newspapers	35
Horticulture Hotline	32
Television	31
Agnotes & Ag Bulletins	31
Articles in industry magazines	22
Chemical representatives	19
Radio	15
Video	12
Consultants - private	10

Chemical recommendations

Cropwatch suggests chemicals which are best suited to the conditions, and the target pests and diseases. These chemicals are also the ones we believe have the least effects on beneficial insects. These recommendations are based on our knowledge and experience.

Cropwatch does not support one chemical manufacturer over another, and will avoid criticising any of the chemicals currently on the market.

Similarly, we prefer to use the common names of chemicals, rather than trade names, as the latter would infer we support one chemical brand over another. Growers can easily find trade names of chemicals by consulting their chemical reseller or the "Vine Pest and Disease Control Chart" sold by the Department of Food and Agriculture. □

Events to look forward to:

- Spray calibration workshops - To be run by Rob Hayes and Reg Johns of Sunraysia Horticultural Centre between 12 noon - 2 p.m. at :
  Red Cliffs, Thursday 27 August
  Mildura, Wednesday 2 September
  Coomealla, Thursday 3 September
  Merbein, Thursday 10 September
  Robinvale, Wednesday 16 September
  (Robinvale to include other information and topics!)

  Growers should contact Rob Hayes or Reg Johns (050) 514500 for further information.

- Field days on trellis structures and end assemblies - on the afternoon of Friday 18 September at Sunraysia Horticultural Centre. Contact Rob Hayes at Sunraysia Horticultural Centre for further information.

- Wine Industry Technical Conference, Melbourne, 26-29, 1992. A must for all winegrape growers and winery staff. Enquiries to the Australian Wine Research Institute (Judy Philpott) on (08)379 1111.

Appendix 7 AusVit: Expert system for grapevines

a) **AusVit: Australian Viticultural Management Expert System.**

J.W. Travis and Co-authors (including R.D. Magarey and R.W. Emmett).

Paper published in Aust. Grapegrower & Winemaker No. 340:117-118 (1992).

AusVit: Australian Viticultural Management Expert System

James W. Travis

Visiting Scientist
Loxton Research Centre
SA Department of Agriculture
and Co-authors listed in Table 1

A vineyard management package is being developed by a team of Australian and overseas scientists, to help grapegrowers make better vineyard management decisions. Initial phases have just been completed in the project sponsored in part by the Australian Grape and Wine Research and Development Corporation and the Dried Fruit Research Council.

Agricultural production worldwide has evolved into a complex business requiring the accumulation and integration of knowledge and information from many diverse sources including marketing, viticulture, insect and mite management, disease management, weed management, irrigation and accounting. Very seldom do farm managers have all the available information in a usable form at their disposal when management decisions must be made. Increasingly, the modern grower must become an expert in the acquisition of information for decision making in order to remain competitive. One way to make this information readily available is through the use of expert systems.

Integrated viticultural management programmes can deliver to growers more precise and effective management recommendations. AusVit, a viticultural management expert system, is



• Some of the viticultural specialists who are building AusVit, at the first te planning meeting at the Waite Agricultural Research Institute, Adelaide, 10 March, 1992. From the back they are Bryan Coombe, Phil Nicholas, Peter Hay Peter Magarey, Malcolm Wachtel, Gavin Ash, Geoff Furness, Brian Freem Roger Polkinghorne, Pat Ellison, Bob Emmett, John Gray, Tan Nair, Peter I Roger Magarey, Jim Travis, Neville Herrmann and Ross Turkington. E Robinson, photographer.

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being developed to assist growers in decision making. An expert system is a computer programme designed to simulate the problem-solving behaviour of a human who is an expert in a specialised area. The objective of the co-operative effort is to develop an Australian viticultural expert system that will manage grapes in all states of Australia.

Since the information needed to assemble a meaningful expert system is derived from many areas, a team approach to development is being taken. Viticultural specialists from across Australia (as listed in Table 1) are co-operating on the development of AusVit. The interaction of this team in designing various components of AusVit is portrayed in Figure 1. AusVit covers a range of viticultural problems encountered by a grapegrower and is being built as a series of modules or sub-units; viticulture, insects and disease (Figure 2).

The viticultural module of AusVit includes a petiole analysis component which describes decision making for each mineral. Each mineral is rated as deficient, marginal, satisfactory or luxury. The mineral rating level is based on laboratory test results and various other factors such as cultivar, deficiency and toxicity symptoms, foliar spray applications and rootstock. A recommendation is given for each mineral based on the rating given by the expert system, past fertiliser applications, past petiole analyses, and soil acidity. The mineral modules which will be built separately, will interact with each other to provide an integrated fertiliser recommendation for the grapegrower.

Insect modules are being developed for lightbrown apple moth, mealy bug and mites. These modules will determine if the insect in question is over or under a threshold level. No control action will be undertaken for insects under threshold. If a module determines an insect is over threshold, the information will be passed to the next level of decision making which is the control module. Chemical selection will occur depending on the insect, integrated pest management strategy, vineyard conditions and compatibility with other pesticides being recommended by AusVit.

Disease modules are being developed for powdery and downy mildew, black spot, *Botrytis*, and phomopsis. Initially the pathology modules will rate the disease risk for the vineyard based on cultivar susceptibility, disease incidence, microclimate and forecast weather conditions and viticultural factors in the vineyard. When the disease risk has been estimated for each disease, the rating will be used to determine a control strategy. The decision to apply fungicides or not will be based on the risk rating for each of the diseases, the growth stage of the vineyard and days-to-harvest limitations for each fungicide as well as market destination of the crop.

Recommendations from each viticulture, insect and disease module will be integrated into a whole vineyard recommendation for winegrapes, dried vinefruit and table grape growers. Each recommendation will be tailored to the vineyard from which the information was collected.

Preliminary versions of the expert system will be available for grower inspection late in 1992. Vineyard testing is scheduled to begin in 1993 with release of AusVit expected in 1994 or 1995. The AusVit expert system should be one of the most useful tools for accomplishing the task of providing growers with the day-to-day, integrated support needed to manage grapes in Australia.

Table 1. AusVit co-operators and area of contribution.

Viticulture	Address
Bryan Coombe	Waite Agric. Res. Inst., PO Box 1, Glen Osmond SA 5064
John Gray	Waite Agric. Res. Inst., PO Box 1, Glen Osmond SA 5064
Peter Hayes	Grape & Wine Res. Dev. Corp, Payneham SA 5070
Phil Nicholas	Loxton Res. Centre, PO Box 411, Loxton SA 5333
Ben Robinson	Scholefield Robinson, Hort. Services, Kingswood SA 5062
Entomology	
Greg Buchanan	Sunraysia Hort. Centre, Box 905, Mildura Vic 3502
Geoff Furness	Loxton Res. Centre, PO Box 411, Loxton SA 5333
David Madge	Sunraysia Hort. Centre, Box 905, Mildura Vic 3502
Plant Pathology	
Bob Emmett	Sunraysia Hort. Centre, Box 905, Mildura Vic 3502
Russell Johnstone	AWRI, PO Box 197, Glen Osmond SA 5064
Peter Magarey	Loxton Res. Centre, PO Box 411, Loxton SA 5333
Roger Magarey	Sunraysia Hort. Centre, Box 905, Mildura Vic 3502
Tan Nair	NSW Agric., PMB 10, Rydalmere, NSW 2116
Ross Turkington	Gosford Hort. Centre, PO Box 581, Gosford NSW 2250
Malcolm Wachtel	Northfield Res. Centre, GPO Box 1671, Adelaide SA 5001
Knowledge Representation & Computer Programming	
Gavin Ash	Charles Sturt Univ., Wagga Wagga NSW 2650
Steven Cahill	Penn State Univ., University Park, PA 16802 USA
Pat Ellison	Charles Sturt Univ., Wagga Wagga, NSW 2650
Neville Herrmann	Charles Sturt Univ., Wagga Wagga, NSW 2650
Jan McClure	Penn State Univ., University Park, PA 16802 USA
Roger Polkinghorne	SA Depart. of Agric., GPO Box 1671, Adelaide SA 5001
Jim Travis	Loxton Res. Centre, PO Box 411, Loxton SA 5333
Administration	
Chris Green	NSW Agric., PMB 10, Rydalmere, NSW 2116

James W. Travis is from the Pennsylvania State University, USA.

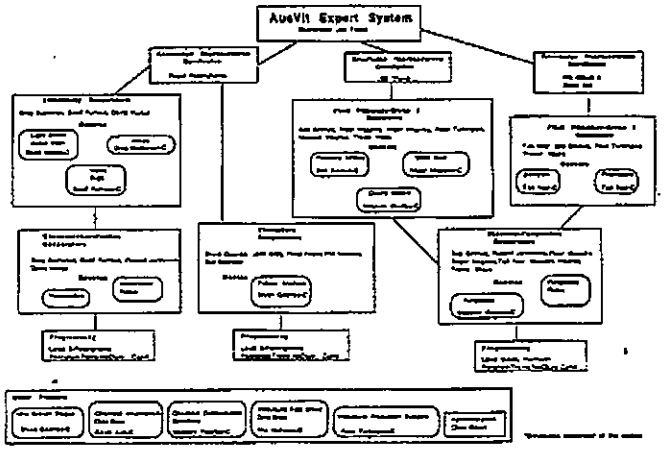


Fig. 1. A flow chart of co-ordination among AusVit co-operators.

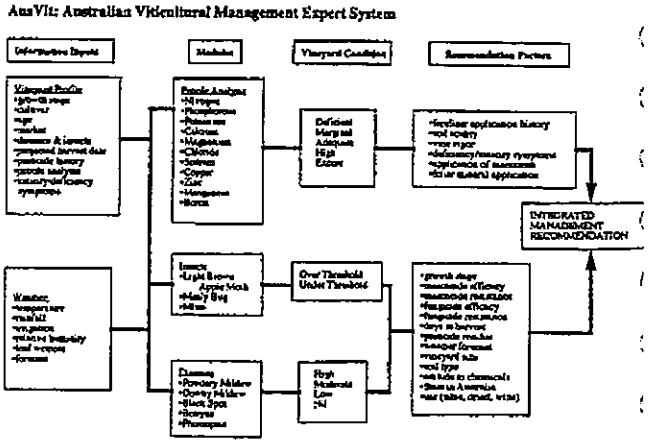


Fig. 2. A chart of the flow of information from vineyard to a recommendation by AusVit.