An IPM approach for managing Botryosphaeria in UK Vineyards

Botryosphaeria: **a family of fungal trunk diseases causing wood necrosis, yield reduction, premature vine death and many other symptoms. Relatively little is known about it, there is no known cure and reported infection rates are rising rapidly.**

Also known as: Black Dead Arm, Excoriose, Diplodia Cane Dieback, Bunch Rot

Up to 30% fruit loss for severe infections (Wunderlich, Ash et al. 2011)

5-10% crop loss No known treatment (CRCV 2005)

Annual losses in Bordeaux from Black Dead Arm 4-20% (Larignon, Fulchic et al. 2001)

In Spain the cork oak suffers from Botryosphaeria (Luque, Pera and Parladé 2008)

Lesions and cankers reduce yield and kill vines

Botryosphaeria produces laccase with associated adverse effects on wine (Alves Da Cunha, Barbosa et al. 2003; Jackson 2008),

Symptoms

❑Symptoms easily confused with other pathogens
- diagnosis purely on symptoms is unreliable hence lab analysis necessary for correct identification (Qiu, Steel et al. 2011; CRCV 2005).
- Easy to confuse pycnidia with dark lenticels (Newsome 2011).

❑Inconsistent reporting of leaf, shoot and berry symptoms may be because most studies have mostly focused on wood cankers (CRCV 2005; Gubler, Rolshausen et al. 2005; Wunderlich, Ash et al. 2011).

❑Botryosphaeria and Eutypa symptoms very similar, except:
- Eutypa causes shortening of internode length, Botryosphaeria does not.
- Botryosphaeria is much quicker to colonise vascular tissue in vines than Eutypa
- Eutypa leaf symptoms are small cupped leaves; not so for Botryosphaeria

(Gubler, Rolshausen et al. 2005; Bonfiglioni and McGregor 2006 ; Savocchia, Steel et al. 2007 ; Úrbez-Torres, Adams et al. 2009)

Most common symptoms and variation between species

- The family is characterised by a confusing array of species, names, symptoms
- Both symptoms and virulence vary between species, region, climate and study
- Cankers often infected with other pathogens hence diagnosis complex

	Botryosphaeria dothidea	*Botryosphaeria parva*	*Botryosphaeria obtusa*	*Botryosphaeria stevensii*	*Botryosphaeria lutea*	*Botryosphaeria ribis*	*Botryosphaeria rhodina*	*Botryosphaeria australis*	*Fusicoccum viticlavatum*	*Fusicoccum vitifusiforme*
❶ Bud mortality	✓	✓	✓							
❷ Shoot dieback	✓					✓	✓			
❸ Elongated black lesions	✓					✓	✓			
Bleached canes	✓	✓	✓	✓	✓		✓			
❺ Trunk dieback	✓	✓	✓	✓	✓		✓			
❹ ❼ Wedge-shaped necrotic lesion	✓	✓	✓	✓	✓	✓	✓	✓		
Dark brown wood discolouration	✓	✓	✓	✓	✓		✓			✓
❻ Brown streaking, black spots	✓	✓	✓	✓	✓		✓			
Infected pruning wounds		✓	✓						✓	
Leaf chlorosis		✓	✓	✓		✓				
Fruit rot	✓					✓	✓			
Graft union failure	✓	✓	✓	✓	✓		✓			

Sources: (Gramaje and Armengol 2011; van Niekerk, Fourie et al. 2006; Phillips 1998; Phillips 2002; Pitt, Huang et al. 2010; UKVA 2011a; CRCV 2005; Qiu, Steel et al. 2011; Úrbez-Torres, Adams et al. 2009; Rolshausen, Úrbez-Torres et al. 2010)

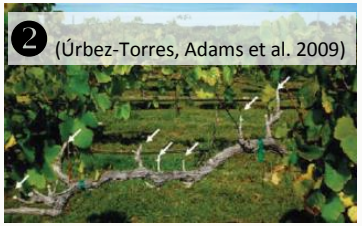

❼ (Savocchia, Steel et al. 2007)

❑Fruit rot
- Is common cause in other hosts (e.g. apples and pears) (Wunderlich, Ash et al. 2011) .
- In grapes, is commonly confused with botrytis and phomopsis (Wunderlich, Ash et al. 2011)
- 1-4mm lesions and pycnidia on berries, which then desiccate (CRCV 2005).

❑Long black lesions on internodes then turn white or grey in autumn and black fruiting structures appear (van Niekerk, Fourie et al. 2006).

❑The trunk staining extends from wound towards root (UKVA 2011a; Gramaje and Armengol 2011) and is caused by toxic fungal excretions (Newsome 2011).


❶ (Jaspers n.d.)


❷ (Úrbez-Torres, Adams et al. 2009)


❸ (Úrbez-Torres, Adams et al. 2009)


❹ (UC Davis 2011)


❺ (van Niekerk, Fourie et al. 2006)


❻ (van Niekerk, Fourie et al. 2006)

Biology

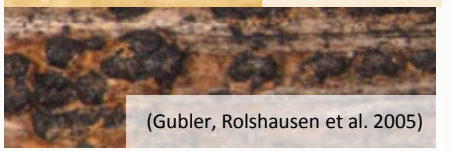
❑**Overwinters**

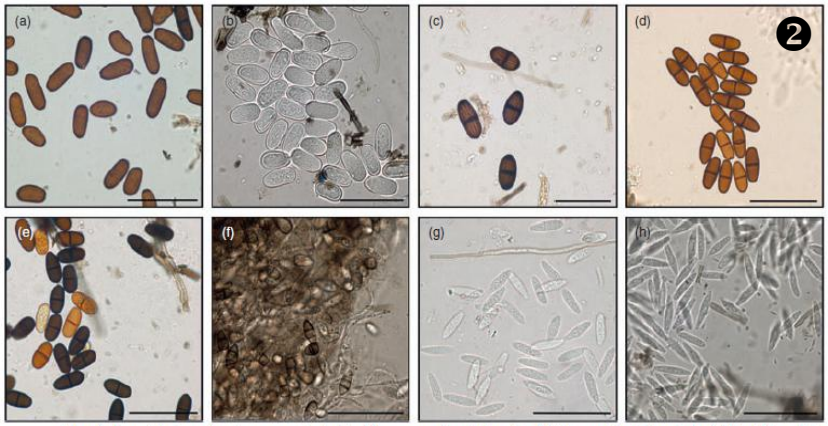
- as small dark pimples, pycnidia ❶ (black fruiting bodies), and as conidia, ascospores and mycelium
- on and under bark of diseased wood, often at base of canes, and on pruning debris.

(Agrios 2005; van Niekerk, Fourie et al. 2006; American Phytopathological Society 1990; CRCV 2005; Gramaje and Armengol 2011; UKVA 2011a).


(Úrbez-Torres, Adams et al. 2009)

(ICGTD 2011)


(Gubler, Rolshausen et al. 2005)



Morphology of Botryosphaeriaceae species isolated from grapevines in New South Wales and South Australia: (a) *Diplodia seriata*, (b) *Diplodia mutila*, (c) *Lasiodiplodia theobromae*, (d) *Dothiorella iberica*, (e) *Dothiorella viticola*, (f) *Neofusicoccum parvum*, (g) *Neofusicoccum australe*, and (h) *Botryosphaeria dothidea*. Bar = 50 µm.

❑**Reproduction**

Spores produced in bark of dead wood, cankers, and mummified fruit

- most commonly asexually: conidia ❷ from pycnidia ❶
- less commonly: ascospores from perithecia

(Rolshausen, Úrbez-Torres et al. 2010; Phillips 2002; Agrios 2005)

❑**Conidia** ❷ are one-celled, around 20 x 10 µm in size

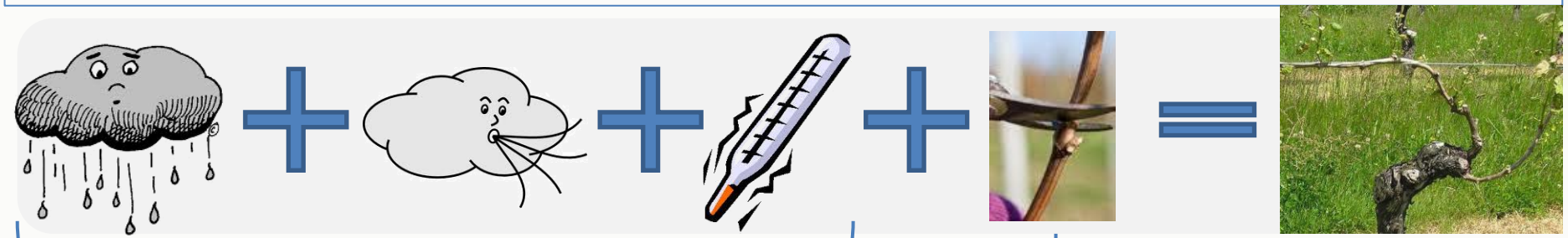
- B. *Diplodia* and *Dothiorella* thick-walled and pigmented
- B. *Fusicoccum* thin-walled and glassy

(American Phytopathological Society 1990; Savocchia, Steel et al. 2007; van Niekerk, Fourie et al. 2006).

❑**Wood infections grow** from wounds mainly towards roots initially causing streaking which in the cross section of the cane looks like diffuse spots then develops to wedge-shaped canker ❸. Cordons with wedge-shaped cankers generally die within 5 years as the wedge covers the whole section of wood (American Phytopathological Society 1990 ; CRCV 2005 ; Gubler, Rolshausen et al. 2005; Savocchia, Steel et al. 2007; UKVA 2011a ; Úrbez-Torres, Adams et al. 2009 ; Úrbez-Torres, Leavitt et al. 2006; van Niekerk, Fourie et al. 2006).

Epidemiology

- **When pruning, mild, wet winter periods are especially risky for infection, hence UK is a problem region** (Rolshausen, Úrbez-Torres et al. 2010, UKVA 2011a)
- **Over 80% of wounds inoculated with Botryosphaeria develop canker** (Rolshausen, Úrbez-Torres et al. 2010)



Spread by rain and splash

- Rainy periods => pycnidia hydrate and grow.
- Rain of only 0.25-1.00mm and humidity leads to spore release.
- Conidia (airborne spores) released from pycnidia in wet and humid environments

Spread by Wind

- Spores travel 3m without wind, 50km with it. Spreads downwind from vine to vine, hence infection of neighbouring vines and sites downwind.

(Agrios 2005; CRCV 2005; Newsome 2011; van Niekerk, Fourie et al. 2006; UKVA 2011a; Gramaje and Armengol 2011; Wunderlich, Ash et al. 2011)

Temperature

Wide range suitable, varying by species and study

- Sporulation 5 or 6°C to 30°C
- Grows up to 37°C

(Copes and Hendrix 2004; CRCV 2005; UKVA 2011a; van Niekerk, Fourie et al. 2006)

Pruning wounds are a principal route of infection and are susceptible to fungal infection for several weeks. (Rolshausen, Úrbez-Torres et al. 2010)

Other routes of infection

- Via lenticels and stomata (Gramaje and Armengol 2011), though lesions are not observed on non-wounded shoots (Savocchia, Steel et al. 2007)
- Even conidia landing on sound berry skins can cause infection (Wunderlich, Ash et al. 2011)
- Major route: from nurseries in young plants (Gramaje and Armengol 2011; Phillips 1998; Rolshausen, Úrbez-Torres et al. 2010; UKVA 2011a; van Niekerk, Fourie et al. 2006)

Disease builds slowly in the vineyard (Taylor, Hardy et al. 2005), but builds up steadily leading to serious decline in vigour (Phillips 1998).

Monitoring

- Monitor thoroughly through visual symptoms of every vine
  - Don't ignore sick or dying vines or uneven vine growth (Smart 2011b) – signs which are quick and simple to see
  - Observe before leaf fall (UKVA 2011a)
  - Cut into wood of suspected vine to investigate (UKVA 2011a) (disinfecting secateurs as appropriate)
  - Tag and map infected vines (UKVA 2011a)
  - Observe wood cross sections when pruning

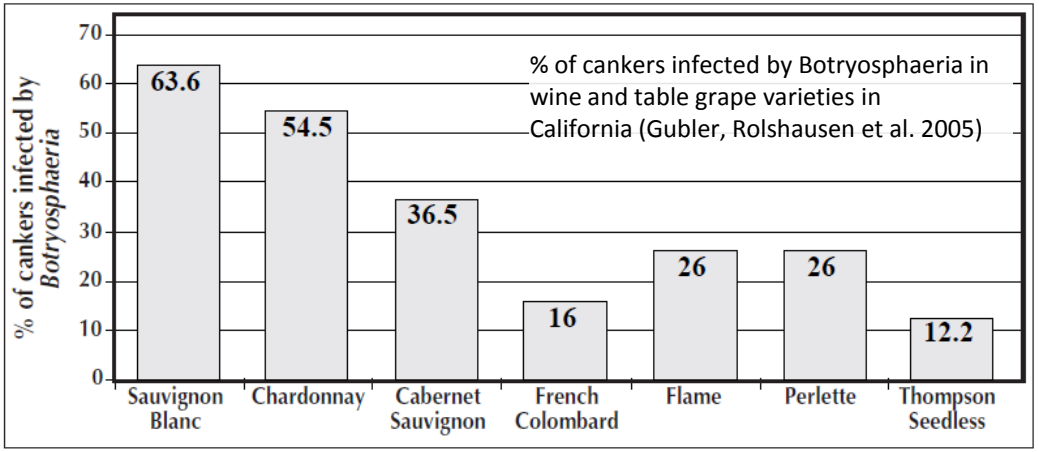
- Testing samples in the lab can be expensive but worthwhile (Smart 2011b). Modern Polymerase Chain Reaction (PCR) techniques have now been adapted to viticulture such that single tests can detect a wide range of fungal pathogens at once (Weir and Graham 2008).

- Take a holistic approach to monitoring. Know the vineyard. Monitor and treat vine nutrition, water status, climate and incidence of other diseases since the effect of botryosphaeria is worsened by other stress factors (Agrios 2005; Bonfiglioni and McGregor 2006; Gramaje and Armengol 2011; CRCV 2005; McNeill 2011c; van Niekerk, Fourie et al. 2006).

- Observe weather so as not to prune when wet. However, after 36 hours of rain the spore count is exhausted, taking 12 days to recharge, so this may give a pruning window (Newsome 2011).

- Observe surrounding vegetation since botryosphaeria has many other hosts, e.g. oak, apples, pears, prunus, ash, elm, pine, various berries (Bonfiglioni and McGregor 2006)

- Monitor susceptible varieties: Rondo, Pinot Noir, Pinot Gris (UKVA 2011a); Sauvignon Blanc, Chardonnay and Semillon (CRCV 2005; Gubler, Rolshausen et al. 2005).



% of cankers infected by Botryosphaeria in wine and table grape varieties in California (Gubler, Rolshausen et al. 2005)

Chemical & biological management methods

Fungicides – *no immediate golden bullet*

- Design is challenging because of varied pathogens (Pitt, Huang et al. 2010 ; Rolshausen, Úrbez-Torres et al. 2010)
- No effective fungal treatment is registered in the UK (UKVA 2011a)
- Benzimidazoles, carbendazim and sodium arsenate unavailable or banned (Newsome 2011)
- Topsin M (Thiophanate-Methyl, which targets mitosis) is somewhat effective against trunk diseases including Botryosphaeria (Rolshausen, Úrbez-Torres et al. 2010), but not approved for vines in UK (UKVA 2011b).
- Boric acid is somewhat effective but toxic and not approved (Newsome 2011; Rolshausen, Úrbez-Torres et al. 2010; UKVA 2011a; UKVA 2011b)
- Maneb is effective against some Botryosphaeracea in the US (van Niekerk, Fourie et al. 2006) but not approved for vines in the UK (UKVA 2011b).
- Nativo (trifloxystrobin+tebuconazole) is approved for vines and known to have some effect on Botryosphaeria (Cooper 2011; Newsome; UKVA 2011b) as is Switch (cyprodonyl+fludioxonil) (Newsome (2011).

Pruning wound treatments – *nothing licensed*

- Either fungicidal or simply as a block (e.g. Acrylic paint)
- Needs to be applied immediately
- 95% effective with topical (brush) application, 40-60% with air blast (Cooper 2011)
- Currently no pruning paint available and permitted for vines in the UK (Cooper 2011; UKVA 2011a)

Trichoderma fungus based products – *needs further study*

- Used to out-compete detrimental fungi
- Can be effective but are slow to establish (Newsome 2011; UKVA 2011a; van Niekerk, Fourie et al. 2006)
- Can be effective as pruning wound protection (Gramaje and Armengol 2011)
- Possible use in planting holes when planting or replanting, 20g trichoderma granules (e.g. Plantmate) to colonise roots, but unproven (McNeill 2011a; UKVA 2011a)

Cultural management methods

Most Botryosphaeria species are probably **'weak' pathogens**, existing on or in healthy vines with little adverse effect

until

other pathogens or stress affects vines too, then serious problems can arise. Infected plants are often symptomless until stressed (Agrios 2005; Bonfiglioni and McGregor 2006; CRCV 2005; Gramaje and Armengol 2011; McNeill 2011c; van Niekerk, Fourie et al. 2006).

Factors predisposing Botryosphaeria susceptibility

- Weak graft unions
- If vines is young and establishing, or if old
- Water stress
- Extreme pH or heavy soils
- Other pathogens or insects
- Heat or frost damage
- And so on

(Bonfiglioni and McGregor 2006; van Niekerk 2006)

hence

Cultural countermeasures in the vineyard

- Canopy management and open bunches to reduce humidity (CRVC 2005)
- Site selection (air-flow, low frost, free-draining and so on)
- Keep other pathogens in check (mildews, botrytis, insects, etc)
- Ensure adequate vine nutrition levels
- Manage drought stress in young vines

Immediate **removal of diseased wood is imperative** (and certainly before winter) - the infection will not go away.

Either: If caught early, remove infected vine parts, cutting >5cm (>10cm (Newsome 2011)) below visible infection and re-train new trunk from water shoot (CRCV 2005; Rolshausen, Úrbez-Torres et al. 2010; Smart 2011b; UKVA 2011a; van Niekerk, Fourie et al. 2006)

Or: Remove whole vine and surrounding vegetation. Replant in following season (UKVA 2011a).

Take diseased wood down-wind and burn.(Agrios 2005; American Phytopathological Society 1990; Gubler, Rolshausen et al. 2005; UKVA 2011a; CRCV 2005; van Niekerk, Fourie et al. 2006).

Management methods for pruning

Perfect control of infection is impossible due to the number of prunings and long susceptibility period (Rolshausen, Úrbez-Torres et al. 2010).

CASE 1, pruning of
- **Infected vines**
- **IF infection is deemed terminal (i.e. canker through trunk and no buds >10cm below infected region) and vine uneconomic**

→ •Don't do it! Grub up immediately, or tag and grub up very soon (UKVA 2011a)

CASE 2, pruning of
- **infected or suspect vines and their neighbours**
- **IF infection deemed recoverable after removing dead wood, and if vine still somewhat productive**

CASE 3, pruning of
- **other vines**

- Prune in late winter since rising sap may carry spores away (Cooper 2011; UKVA 2011a) and wounds heal more quickly (Rolshausen, Úrbez-Torres et al. 2010)
- Prune in dry, cold conditions (UKVA 2011a; CRCV 2005; Rolshausen, Úrbez-Torres et al. 2010)
- Prevent unnecessary wood wounds (van Niekerk, Fourie et al. 2006)
- Leave 3cm stub (UKVA 2011a)

- Spray cane with 50-70% propanol, then cut
- Spray with Nativo 75 WG (3.6g/l) (UKVA 2011a; Cooper 2011)
- Apply acrylic paint to cut surface (UKVA 2011a; Cooper 2011; CRCV 2005)
- Disinfect secateurs between cuts: use propanol or Milton solution (UKVA 2011a)

- Disinfecting secateurs between cuts (Cooper 2011) may be impractical and of limited benefit (McNeill 2011b) and not economic
- Certainly disinfect at the end of every day: use propanol or Milton solution, soaking for 15 minutes (UKVA 2011a)

Management methods in the nursery

- Studies in Spain, Italy, New Zealand and South African have shown nurseries to be a common source of infection in young vineyards (Giménez-Jaime, Aroca et al. 2006; Gramaje and Armengol 2011; Phillips 1998; van Niekerk, Fourie et al. 2006). In a Spanish study *all* the nurseries studied were sources of trunk disease infections: 24% of plants being infected with Botryosphaeriaceae before planting, contributing to 40% of young vineyards having the pathogen present (Giménez-Jaime, Aroca et al. 2006). There are questions as to whether this level of nursery infection carries over into the vineyard due to inter-microbial competition in the vineyard and complex natural environment (Gramaje and Armengol 2011). Other suggest 20% of cuttings from nursery mother blocks infected with Botryosphaeria (Smart 2011a).

- Two studies recommend nurseries protect all pruning wounds on mother vines, both scion and rootstock (Rolshausen, Úrbez-Torres et al. 2010; van Niekerk, Fourie et al. 2006). Another commentator suggests a different route: in the nursery Botryosphaeria spores inoculate new material in hydration tanks (Smart 2011a).

- Cold soaking in fungicides is *not* common practice in French or Spanish nurseries. Nursery practices tend to have high humidity throughout to protect vines from drying out, but this also favours fungal pathogens. Study found presence of Botryosphaeria in planting material increases as nursery process progress though various stages (Gramaje and Armengol 2011). Perhaps planting material should be hot water treated before planting (Smart 2011a; van Niekerk, Fourie et al. 2006), but it's not clear whether this might have longer term detrimental effects (Newsome 2011).

- Perhaps trichoderma fungus formulations should be used as a standard, but this needs to be evaluated further (van Niekerk, Fourie et al. 2006)

- Dip plants with Switch before planting (Newsome 2011)?

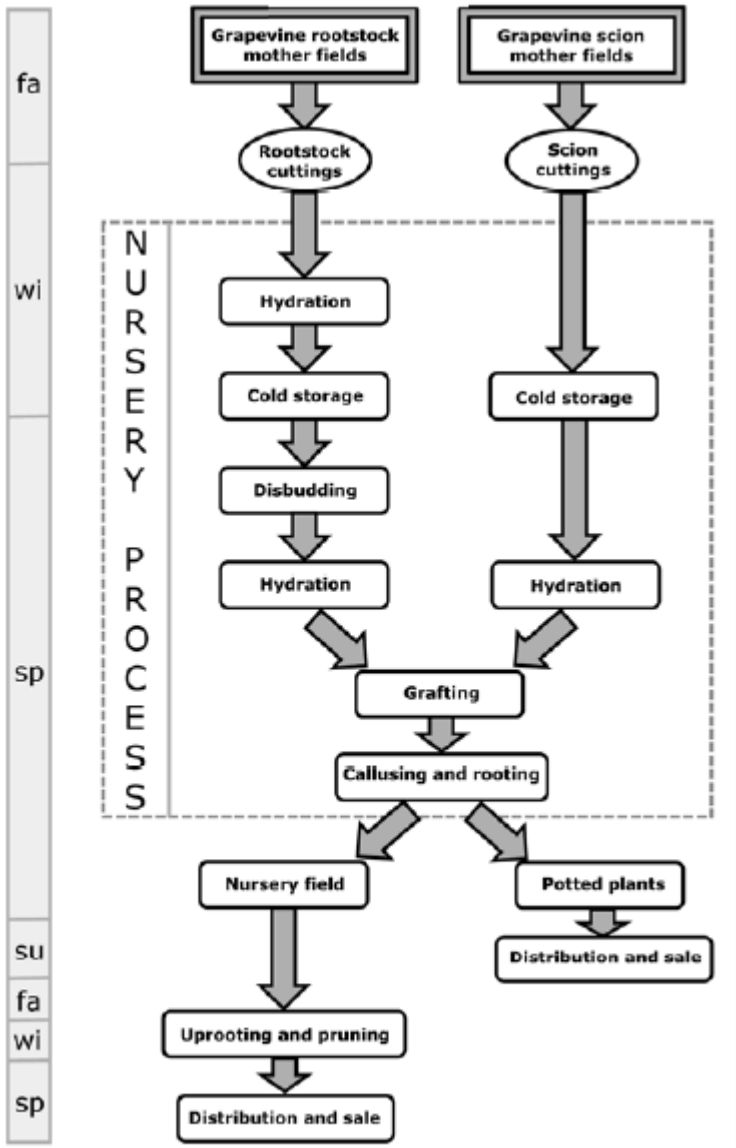


Diagram representing the propagation process of grafted plants in grapevine nurseries. Abbreviations: fa, fall; wi, winter; sp, spring; su, summer. In this figure, the seasons correspond to the Northern Hemisphere.

Recommended IPM approach

- Studying symptoms is essential since identification is the first step to controlling a disease. However, for botryosphaeracea the symptoms are many and varied, and effective management is hard since so little precise information is known about the pathogen (van Niekerk, Fourie et al. 2006).

- An Integrated Pest Management (IPM) approach is required to combat the virulence of botryosphaeria, with a varied approach and reduction of vine stresses:
    - Water
    - Nutrients
    - Weeds
    - Other disease
    - Canopy management
    - Supporting ecology of vineyard through only essential use of chemical treatments

(UKVA 2011a; van Niekerk, Fourie et al. 2006)

- If available, multiple pesticides should be employed to cover range of trunk diseases and to reduce risk of resistance developing (van Niekerk, Fourie et al. 2006). Spray broad spectrum when first exposed leaf is the size of a 50p piece: consider including sulphur, Mancozeb (similar to Maneb), copper, Stroby (kresoxim methyl), Karamate, Switch, and Nativo (Cooper 2011, UKVA 2011a). Trichoderma fungus should be encouraged.

- It is uneconomic to disinfect secateurs between every cut and to apply paint or fungicide to each pruning wound, so thresholds are suggested as previously discussed. These also balance the likely remaining productivity of a partially infected vine with the severe danger it presents for spreading the disease further since an infected vine is destined to die. Removing and replacing one infected vine does cost money, but if the vine is left in the vineyard and the disease spreads then many more will have to meet that fate.

- Monitoring is of paramount importance since limiting the spread is essential as there is no cure for the disease. Take a holistic approach and know the vineyard. It is also important to monitor yield to try to assess the impact of botryosphaeria and so judge the appropriate and economically sound response. Monitor the outcome.

Appendix: reporting and distribution

Various species endemic and abundant in all vineyards worldwide; origin unclear. (Phillips 1998; van Niekerk, Fourie et al. 2006; Bonfiglioni and McGregor 2006)

Dramatic increase in trunk disease symptoms since early 1990s (most dramatically Black-Foot and Petri) (Gramaje and Armengol 2011). Trunk diseases seen as a major threat to the sustainability of viticulture. (Pitt, Huang et al. 2010)

Botryosphaeria is the most common trunk disease pathogen found in Texas, northern Mexico and Spain (Úrbez-Torres, Adams et al. 2009), and some areas of Australia, one study showing 36% if cankers infected with the pathogen (Qiu, Steel et al. 2011; Pitt, Huang et al. 2010). At least some of the growth in reported incidence is from reclassification from other pathogens such as eutypa.

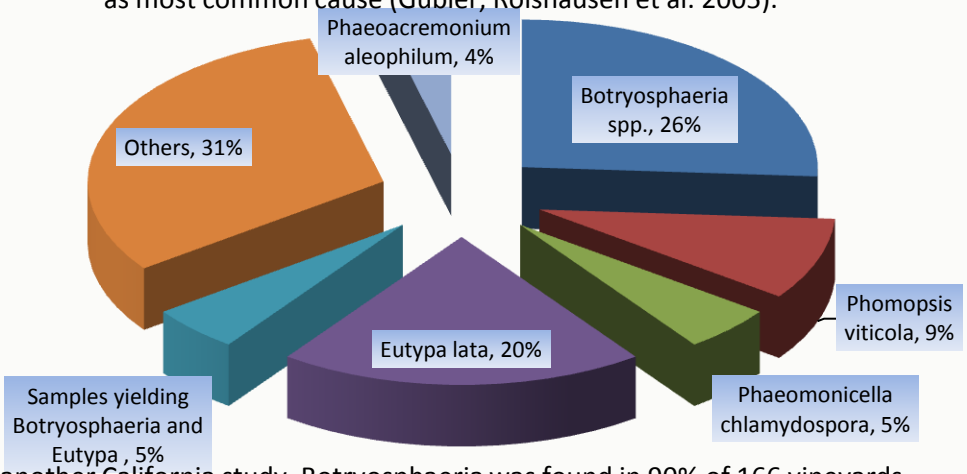
Reporting through time

1990 (American Phytopathological Society)
Tokaj (Hungary), around Naples and Canada

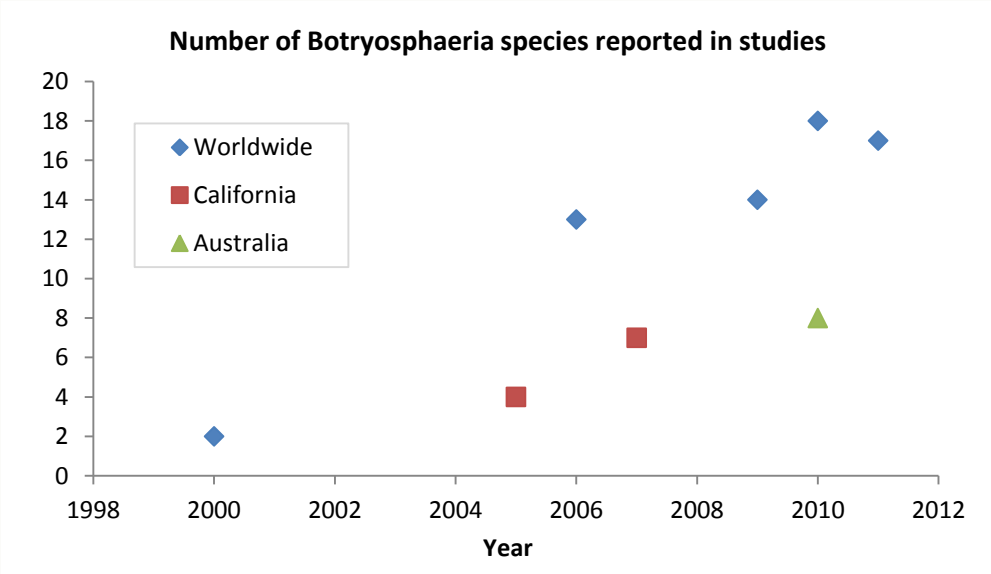
2006 (Úrbez-Torres, Leavitt et al.)
Arizona, California, Mexico, Egypt, France, Spain, Hungary, South Africa, Australia and Portugal

2011 (Smart 2011b; UKVA 2011a)
Observed in 29 of 30 vineyards investigated, though most yet to be confirmed by FERA with lab analysis

Chart showing incidence of various fungi in cankers of vines affected by grapevine dieback in California grapevines, showing Botryosphaeria as most common cause (Gubler, Rolshausen et al. 2005).



In another California study, Botryosphaeria was found in 90% of 166 vineyards and in 47% of 1735 cankers studied (Úrbez-Torres, Leavitt et al. 2006)



Sources: (Pitt, Huang et al. 2010; Gubler, Rolshausen et al. 2005, Úrbez-Torres 2007, Úrbez-Torres, Leavitt et al. 2006, Úrbez-Torres, Adams et al. 2009, Gramaje and Armengol 2011)

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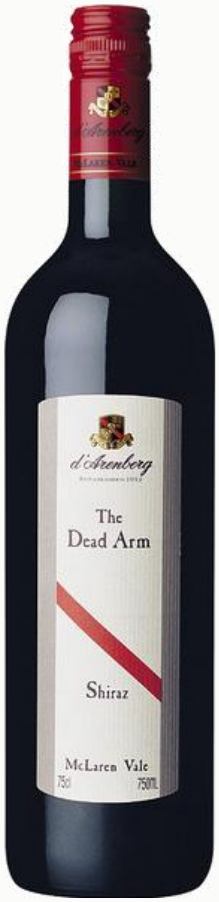

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