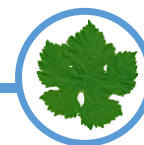


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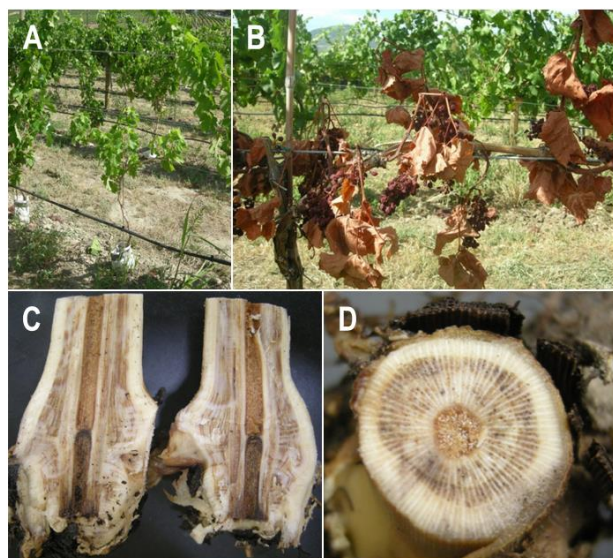


Grapevine Trunk Diseases in British Columbia: From Identification to Control

José R. Úrbez-Torres and Daniel T. O’Gorman, Summerland Research & Development Centre, Agriculture & Agri-Food Canada

INTRODUCTION TO GRAPEVINE TRUNK DISEASES

The long term economic viability of the grapevine industry relies on healthy planting material and practical and sustainable disease management strategies in vineyards. Among the many diseases affecting grapes, grapevine trunk diseases (GTD) are considered one of the most important maladies limiting the lifespan of vineyards worldwide (Gramaje et al. 2018). Grapevine trunk diseases are responsible for substantial economic losses due to yield reduction, an increase in management costs and early vineyard replanting (Kaplan et al. 2016, Siebert 2001, Wicks and Davies 1999). In France for instance, it is estimated that 12% of vineyards (about 100,000 ha) are currently economically unviable due primarily to the GTD esca, with an annual estimated loss of €1 billion (Lorch 2014).

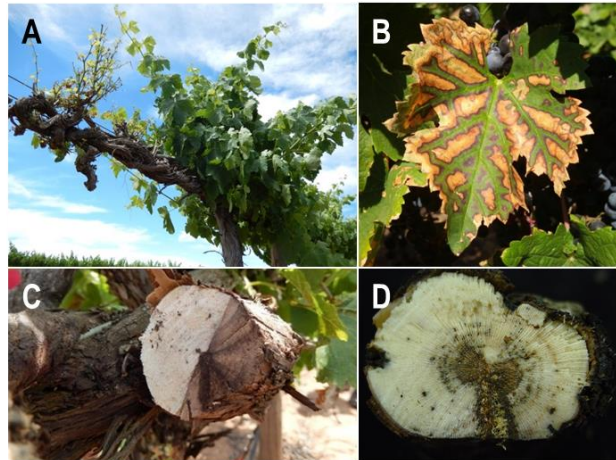


Foliar and vascular symptoms of grapevine trunk diseases in young vines. Poor vigor (A) or sudden collapse (B) during the growing season can be observed. Longitudinal/cross sections of infected vines show wood necrosis caused by the fungal infection.

Grapevine trunk diseases are caused by many different fungal pathogens, whose spores infect grapevines primarily through pruning wounds. In addition, it has been shown that some of these fungi are also present in the ready-to-plant nursery material (rootstock and/or scion) and thus, they can be introduced in newly established vineyards (Gramaje and Armengol 2011). Fungal pathogens responsible for GTD colonize the vascular system of the plant causing wood necrosis and/or perennial cankers, which limit water and nutrient movement through both xylem and phloem causing a rapid or slow decline depending on the fungi involved. Eventual death of vine parts (spurs, cordons and/or trunk) or of the entire plant occur when the growth of the cankers cut off the vascular flow.

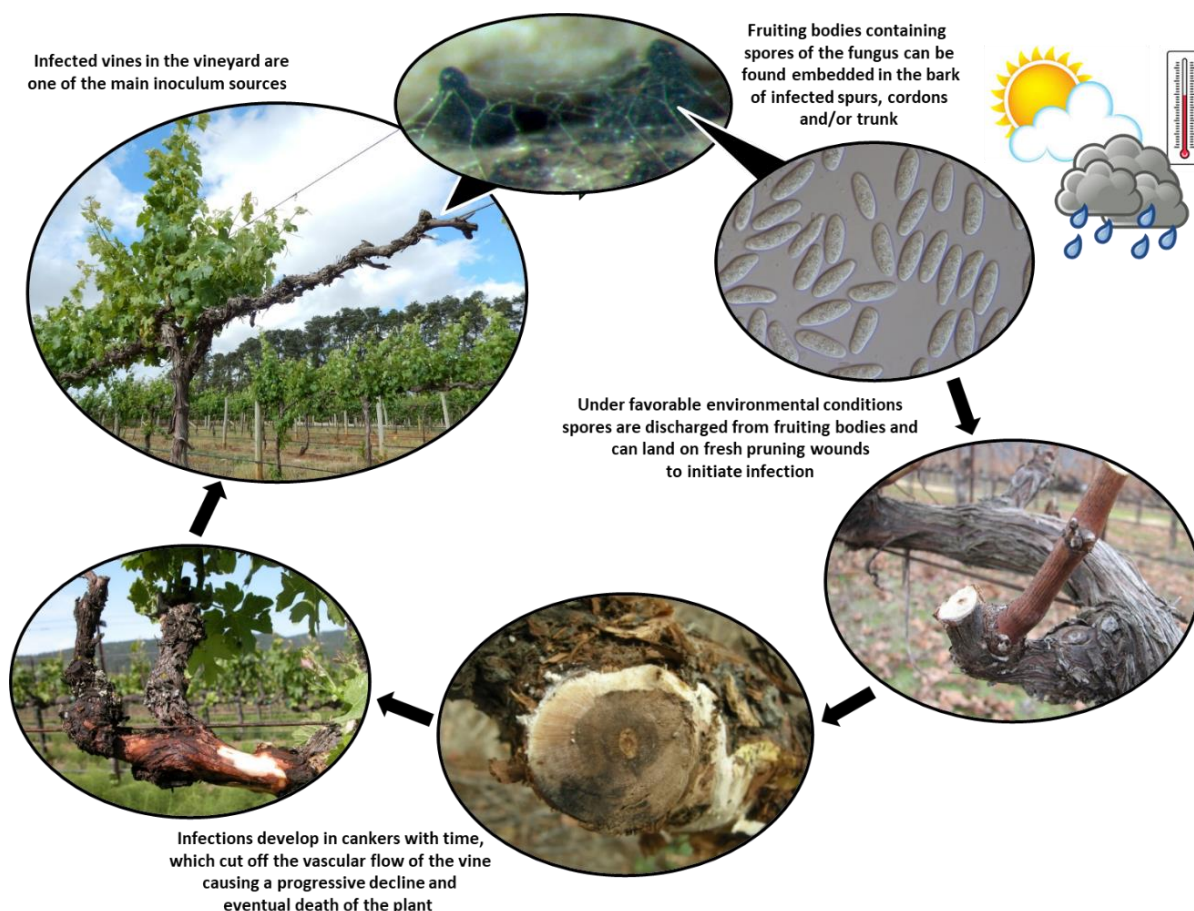
Grapevine trunk diseases are thought to be as old as vine cultivation and references to esca-like

symptoms are found in ancient Greek and Medieval written works (Mugnai et al. 1999). However, the first official research studies on GTD were published in France in 1898 (Ravaz 1898) and in the United States of America in 1914 (Reddick 1914). Though GTD have long been present in vineyards, they have only recently been recognized as a major issue in viticulture. It is currently accepted that these emerging diseases occur wherever grapes are grown and major disease outbreaks have been reported since late 1990s around the world. The urgent need to understand these diseases in order to develop and implement effective management strategies for the grape and wine industry has resulted in intensive research being conducted on this subject during the past two decades in different grape-growing regions (Agustí-Bisach and Armengol 2013, Bertsch et al. 2013, Cloete et al. 2015, Gramaje and Armengol 2011, Mostert et al. 2006, Úrbez-Torres 2011).



Foliar and vascular symptoms of grapevine trunk diseases in mature vines. *Eutypa* dieback causes shoot distortion (A) and perennial cankers (C). Esca disease is characterized by leaf symptoms known as "tiger-stripes" (B) and necrosis and yellowish-soften wood (D).

Overview of the disease cycle of grapevine trunk diseases



GRAPEVINE TRUNK DISEASES IN BC

However, GTD have been long overlooked in British Columbia (BC) and in Canada in general, where symptoms of these diseases may have been confused in the past with winter damage or winter kill. Once the vine is infected, GTD symptoms can take several years to express. Therefore, the still young grape and wine industry of BC did not start recognizing GTD to be a problem until the end of 2000s, when most established vineyards were between 10 and 15 year-old and GTD symptoms could then be better identified. Concerns about the status and impact of GTD in BC resulted in considering them as a research priority by the grape and wine industry in 2010. Accordingly, two research projects were funded by the BC Wine Grape Council (BCWGC) with matching funds from Agriculture and Agri-Food Canada (AAFC) between 2010 and 2018 under the Growing Forward 1 Developing Innovative Agri-Products Initiative (DIAP) and Growing Forward 2 Agri-Innovation Program (AIP) research initiatives. The main objectives of these research projects were:

- Determine the presence and significance of GTD in BC.
- Identify and characterize the fungal pathogens present throughout BC vineyards.
- Develop accurate, rapid, and cost-effective molecular detection tools for GTD fungi.
- Determine the presence of GTD pathogens in vineyards throughout the season.
- Determine the healthy status of nursery planting material for GTD fungi coming to BC.

AGRICULTURE & AGRI-FOOD CANADA RESEARCH INTO GRAPEVINE TRUNK DISEASES

Field surveys were conducted between 2010 and 2013 in over 200 vineyards by the Plant Pathology research team at the Summerland Research and Development Centre (SuRDC) to answer some of these questions. These field studies included assessment of foliar symptomatology from over 60,000 vines and pathogen isolation and identification from over 500 symptomatic vines. Additionally, work was conducted to develop molecular diagnostic tools to accurately and rapidly identify GTD fungi. Results from these studies revealed:

- All GTD, including *Botryosphaeria* dieback, *Eutypa* dieback, *Phomopsis* dieback, esca, black foot, and Petri disease were found throughout BC vineyards in the Okanagan, Similkameen, and Fraser valleys, and the Vancouver and Gulf islands (Úrbez-Torres et al. 2014a, 2014b).
- GTD symptomatic vines were found in 90% of vineyards surveyed.
- It was concluded that approximately 10% of the total vines growing in BC were infected with at least one GTD pathogen in 2014.
- Vineyard blocks showed on average between 2% and 55% disease incidence.
- Individual young (< 6 year-old) and mature (> 6 year-old) vineyards showed up to 40% and 80% disease incidence, respectively.
- In total, more than 40 fungal pathogens causing GTD were identified and characterized in BC (Úrbez-Torres et al. 2015a).
- A diagnostic molecular tool (DNA-microarray) capable of detecting and identifying up to 61 fungal species in one single test in less than 48 h was developed (Úrbez-Torres et al. 2015b).
- Implementation of the abovementioned diagnostic tool was conducted to assess over 150 ready-to-plant vines from two different nurseries. Results showed GTD fungal pathogens to be present in the

roots, rootstock, graft-union and/or scion in 92% of the tested nursery vines. This study also showed a high percentage of GTD fungi detected from asymptomatic vascular system of nursery vines (Úrbez-Torres et al. 2017a).

A research study to understand when GTD fungi were present in vineyards in the Okanagan Valley throughout the year started in 2013. This information is critical to know both the highest and lowest risk of infection periods throughout the year in order to develop and implement control strategies under BC conditions. For this study, five spore traps were placed in vineyards in different locations in the North, Central and South Okanagan Valley. These spore traps collected air containing potential GTD spores in special tubes 24 h/day during 7 days/week for 3 years. Total quantification of GTD spores throughout the year was possible using a molecular tool developed by the SuRDC Plant Pathology laboratory. Overall results showed spores of GTD fungi (Botryosphaeriaceae and Distypaceae spp.) to be released intermittently throughout the growing season (March/April to October) in the Okanagan Valley. In summary, the first high spore release was usually detected at the end of winter beginning of spring when average temperatures were above freezing and correlated, though not always, with rainfall. The highest number of spores were overall detected during the months of May and June (Úrbez-Torres et al. 2017b). Results from this study can be used to develop more effective control strategies by optimizing pruning wound chemical and/or biological agent treatments as well as identifying how pruning can be manage in BC to reduce infection by GTD fungi.

These studies have shown the importance of GTD in BC and laid the foundation for the development of most needed management strategies that will contribute to minimize the economic impact of these diseases on short- and long-term. However, contrary to most grape-growing countries around the world, neither cultural practices nor registered products (chemical and biological) are currently available to fight these diseases in Canada.

GOING FORWARD

Building on previous work, the SuRDC Plant Pathology team will primarily focus its research efforts on developing and implementing effective and sustainable control strategies against grapevine trunk disease (GTD) for both BC and Canada. In order to accomplish this, a research project, entitled *“From nursery to vineyard: implementation of effective management strategies against grapevine trunk diseases in Canada,”* was recently funded by the BCWGC with matching funds from AAFC. This research project is one of many awarded in the Grape and Wine Cluster under the Canadian Agricultural Partnership (CAP) - AgriScience Program and led by the Canadian Grapevine Certification Network (CGCN). This research project will last until March of 2023, and the main objectives include determining what stress factors favor GTD disease development in newly established vineyards, and investigating and implementing existing and novel management strategies against GTD.

Because our completed studies have shown a high percentage of asymptomatic ready-to-plant grapevine nursery material harbor GTD fungi, we believe that several of these fungi can act as *“latent pathogens”* in nursery material – becoming virulent when the vine is under abiotic stress conditions. Accordingly, we will study the effect that some of these stressors have on disease development. The aim of this objective is to determine best planting conditions to minimize the impact the GTD have on young vineyards. The latter objective will include assessment of chemicals and/or biological control agents for

pruning wound protection and development of best cultural practices to mitigate GTD under BC growing conditions.

Current research and preliminary work supporting these objectives shows promising results on the assessment of both chemical products and biological control agents. Consequently, the SuRDC Plant Pathology Laboratory in collaboration with the Minor Use Pesticide Program are working towards product registrations on grapes in Canada. Significant progress is being made on the development of cultural practices under BC conditions, including remedial surgery and the understanding of how pruning can be utilized to reduce infection caused by GTD. In addition, the Plant Pathology team will work together with SuRDC scientist Dr. Pat Bowen to develop drone and/or ground-based imaging techniques to detect GTD symptoms. In collaboration with SuRDC biologist Carl Bogdanoff, we are studying the effects of GTD on plant health and bud hardiness.

Further results from these studies will be presented at the 11th International Workshop on Grapevine Trunk Diseases, which will be held for the first time in Canada, July 7-12, 2019. The SuRDC Grape and Wine team will host this international event at the Lakeside Resort and Conference Centre in Penticton. This is a unique opportunity for Canada and BC to learn the latest research findings on different areas concerning GTD from scientists and industry members from around the world.

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