Winter climate and cultivar effects on severity of Pierce's Disease in table grapes

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ABSTRACT

Grapevines infected with *Xylella fastidiosa* can recover from infection following exposure to cold temperatures. The rate at which vines recover is dependent on duration of cold exposure, cultivar susceptibility, and time of inoculation. Previous studies primarily focused on climate conditions experienced in the northern California wine grape growing regions, and only a small number of cultivars. This study aims to increase available information on probability of vine recovery in warmer regions. Cold treatment representative of southern California climate conditions led to very low rates of recovery in susceptible grapevines. However, even at low chill hour treatments, rate of recovery varied based on cultivar and time of inoculation. Comparison of *Xf* strains isolated from northern and southern California locations did not show any significant difference in curing under the same conditions. Evaluating the rate at which *Xf* infected grapevines can be cured by cold temperatures is important for developing region-specific management strategies, and for understanding pathogen spread in a variety of locations.

Keywords: *Xylella fastidiosa*, climate, Pierce's Disease, cultivar, winter-curing

INTRODUCTION

In California, epidemiology of Pierce's disease (PD) of grapes, caused by *Xylella fastidiosa*, is dependent on regional climate variation and insect vector species. Disease develops more quickly, and symptoms are more severe when temperatures are high during the summer, and the pathogens range is generally limited to warmer climates [1]. PD strains of *X. fastidiosa* are inherently sensitive to low temperatures and cold treatment can effectively eliminate *X. fastidiosa* from infected plants [2, 3]. In the

field, winter conditions can eradicate infections in grapevine and almond, particularly when the plants become infected late in the growing season [4-6]. This phenomenon, termed "overwinter curing" is an important consideration for disease management and epidemiology. However, current knowledge of overwinter curing is limited to studies conducted in the northern California wine grape growing regions, using a limited number of wine grape cultivars [7]. In northern California, vector control early in the growing season is used to manage blue-green sharpshooter populations and to prevent early season infections with *Xf* [8]. Late season infections are not problematic in northern regions because it is likely that they will be cured over the winter. In southern California regions such as the lower San Joaquin Valley and the Temecula region, Glassy-winged sharpshooter is the primary vector [9]. In these areas, secondary spread is more of a concern, and winter conditions may not be cold enough to prevent infection reoccurrence [10, 11]. Glassy-winged sharpshooter populations can be high late into the summer [12], and decisions about when to implement vector control measures need to consider the possibility that late season infections may persist . Additionally, as some cultivar variation has been observed in rates of overwinter curing [7], it is important to evaluate a wider variety of wine and table grape cultivars so that specialized recommendations can be made for areas with high disease pressure. The purpose of this study is to better understand the frequency of overwinter curing under Southern California climate conditions so that region-specific management strategies can be developed. This information also will be useful in evaluating spread of PD in other locations around the world that have very warm winter climates.

Southern California chill hours have minimal curing effect on *X. fastidiosa* infected grapevines. Different grape-growing regions within California have varied winter temperatures. Chill hours, measured as cumulative number of hours below 45 degrees (Fahrenheit), can range from 0 to greater than 2000 within the state of California in each year. In the Temecula region and the southern San Joaquin Valley where PD is problematic, number of chill hours is significantly lower than the North Coast and Napa regions where overwinter curing is known to occur (Table 1). Grapevines (*Vitis vinifera* Chardonnay) were artificially inoculated with *X. fastidiosa* [13] and grown for 12 weeks for infections to become established. Then infected plants were subjected to treatment in a cold chamber at 40°F for different lengths of time to

replicate chill hours experienced in different regions of California (Fig. 1). Following cold treatment, plants were grown back from dormancy, and evaluated for continued infection by PCR after 16 weeks of re-growth. At lower chill hours, vine recovery was minimal, but increased with longer duration of cold treatment (Fig. 1). This suggests that under conditions representative of climate in southern California regions, curing is less likely once plants become systemically infected.

Time of inoculation is still important at low chill hours. Because time of inoculation can affect rate of curing, grapevines were artificially inoculated at multiple timepoints throughout the summer. These vines were subjected to cold treatment at 40°F for 800 hours to represent the colder end of the southern California temperature range. Plants that were treated after 8 weeks post-inoculation had a higher curing rate than plants that were treated at 18 weeks post-inoculation (Table 2). This shows that even at low chill hours, time of inoculation prior to cold exposure can still influence vine recovery.

Northern and southern California *X. fastidiosa* isolates are cured at the same rate. To investigate whether different isolates of *X. fastidiosa* strains in California have adapted to different climate regions, rates of overwinter curing were compared in plants inoculated with *X. fastidiosa* Stag's Leap, a northern California isolate, and *X. fastidiosa* Bakersfield-1, an isolate obtained from the southern San Joaquin Valley in 2016 (Table 2). These strains are characterized as subspecies *fastidiosa*, and are closely related based on multi-locus sequence typing. Grapevines inoculated with Stag's Leap and Bakersfield-1 had very similar rates of curing when treated after 8 or 18 weeks post-inoculation. It is likely that at least within California, strains of *X. fastidiosa* causing PD, have a similar response to cold temperatures.

Grapevine cultivar influences rate of curing. As previous studies of overwinter curing focused on a limited number of wine grape varieties, we evaluated twelve different table grape cultivars for rate of overwinter curing. Varieties screened included Autumn Royal, Autumn King, Crimson Seedless, Red Globe, Flame Seedless, Princess, Scarlet Royal, Summer Royal, SugarOne, Thomson Seedless, Valley Pearl, and PD tolerant rootstock variety Tampa. Cabernet Sauvignon was included for comparison as this cultivar has been used extensively in previous studies of overwinter curing. Vines

were inoculated with *X. fastidiosa* Stag's Leap as described above, and infections were allowed to progress for 16 weeks. Infection status was determined using qPCR prior to cold treatment at 40°F for 800 hours. Following cold treatment, vines were grown back from dormancy for 16 weeks, and tested with qPCR and visual symptom evaluation for reoccurrence of infections. Number of plants infected before and after cold treatment is shown in Figure 2. Some highly susceptible cultivars such as Red Globe are difficult to evaluate because of severe PD symptoms leading to high vine mortality. However, Cabernet Sauvignon had a higher rate of curing compared with some susceptible table grape varieties such as Scarlet Royal. This highlights the importance of evaluating the different cultivars for rate of overwinter curing under different climate conditions.

Future prospects

It is likely that overwinter curing of grapevines infected with *X. fastidiosa* does not occur consistently in southern California grape-growing regions. To the extent that overwinter-curing does occur in southern regions, time of inoculation is still important for predicting the amount of vine recovery. A wider range of cultivars, including both wine and table grapes need to be evaluated for overwinter curing under a variety of climate conditions. Additionally, field studies using mechanically inoculated grapevines are necessary to fully understand the extent to which overwinter curing can be predicted across different regions, and in different cultivars.

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Table 1. Chill hours in California (2017-2018)

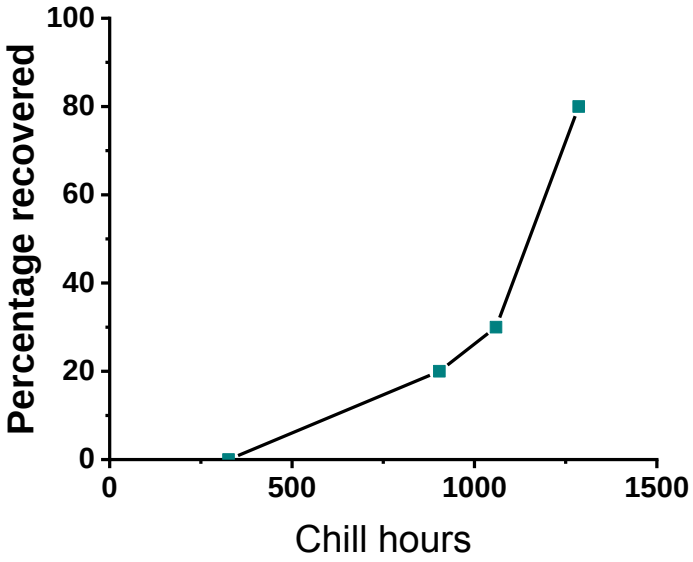
Location	**Hours <45F**
Temecula	171
UC Riverside	191
Arvin (S. San Joaquin Valley)	851
Parlier	977
Napa	1084
Mendocino (North Coast)	1194

Data compiled by the University of California - Davis Fruit & Nut Research & Information Center (http://fruitsandnuts.ucdavis.edu/Weather_Services/chilling_accumulation_models/Chill_Calculators).

Table 2. Effect of *X. fastidiosa* strain and time of inoculation.

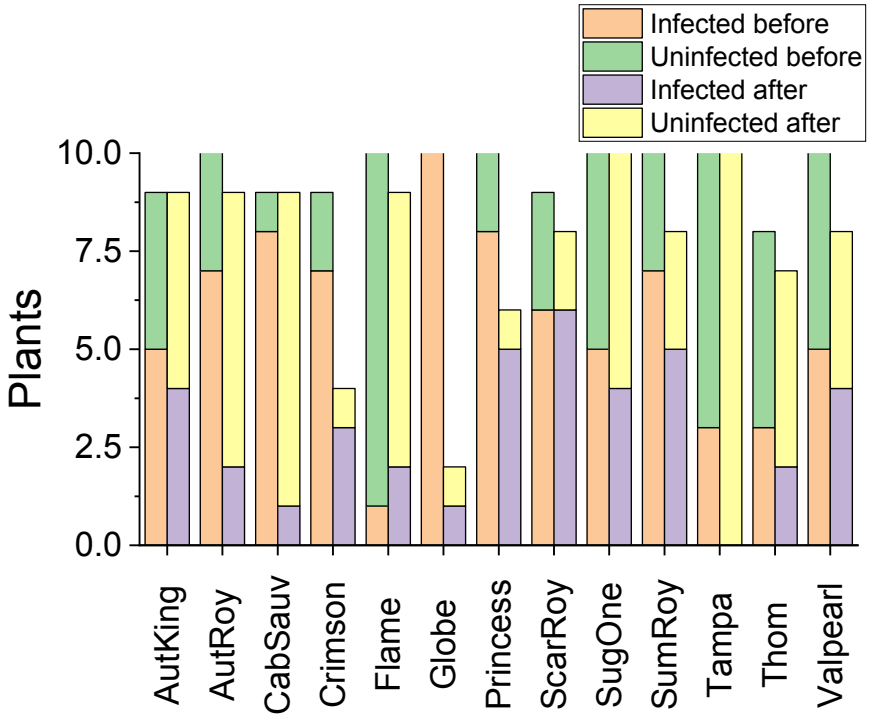
Weeks post-inoculation	**Strain**	**Plants infected after treatment**
8	Bakersfield 1	12/20
8	Stag's Leap	10/20
18	Bakersfield 1	18/20
18	Stag's Leap	17/20

Fig. 1. Effect of number of chill hours on vine recovery.



Susceptible grapevines (*Vitis vinifera* Chardonnay) were inoculated with *X. fastidiosa* Stag's Leap and then after 16 weeks post-inoculation, subjected to cold treatment at 40°F for varied lengths of time. Vines were tested before and after cold treatment to confirm infection status using qPCR. Recovered vine were determined as those that tested positive or *X. fastidiosa* prior to treatment and negative for *X. fastidiosa* 16 weeks after treatment. A total of 20 vines was included in each cold treatment.

Fig. 2. Effect of cultivar on overwinter curing.



Vines inoculated with *X. fastidiosa* Stag's Leap were subjected to cold treatment at 40°F for 800 hours. Infection status was determined before and 16 weeks after treatment using qPCR.