Title
Evaluating Potential Shifts in Pierce's Disease epidemiology

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Reporting Period
The results reported here are from work conducted November 2017 to February 2018.

Abstract
In this report we present 2016 and 2017 Pierce's disease incidence in 32 study blocks and we focus on the potential role of climate change, notably winter temperatures, on the recent Pierce's disease (PD) epidemic in the North Coast. Winter temperatures are key to PD epidemiology because of the vine recovery phenomenon, where some plants recover from *X. fastidiosa* infection if vector inoculations occur late in the growing season or if winters are cold. Therefore, warmer winters could be correlated with PD incidence, suggesting changes to PD ecology leading to fewer plants recovering from infections from one year to another.

Lay Summary

A PD epidemic emerged in Napa and Sonoma counties. Very high PD prevalence was reported throughout the region, with a large number of stakeholders reaching out to UCCE Farm Advisors. In summer 2015, the project team held a series of joint meetings/field visits with the Farm Advisors. Two observations have been made that raised our concern about the problem. First, high prevalence of PD in the North Coast is usually below 1-2% per vineyard; several vineyards visited had over 25% of vines symptomatic. Second, historically PD is closely associated with riparian zones in the North Coast; we have visited several vineyards where PD does not appear to be associated with riparian zones. We have observed these greater rates of disease incidence and dissociation with riparian areas throughout Napa and Sonoma counties—they are not district specific. The goal of this proposal is to determine what factors are driving this epidemic, so that ecology-based disease management strategies can be devised and immediately implemented, as was successfully done in the past when disease drivers appear to have been different.

Introduction

Pierce's disease of grapevine (PD) has reemerged in Napa and Sonoma counties, where disease incidence has been much higher than usual and the distribution of sick vines within vineyards often does not fall within expectations. These field observations taken together with the very high number of vineyards affected in the region indicate that a PD epidemic is emerging. The goal of this proposal is to determine what factors are driving this epidemic, so that ecology-based disease management strategies can be devised and immediately implemented, as was successfully done in the past when disease drivers appear to have been different. In this report we summarize progress made trying to understand if climate is a significant factor driving the most recent PD epidemic in the North Coast.

Objectives

Objective 1. Vector, pathogen, and host community surveys to inform the development of a quantitative model to assess future Pierce's disease risk and develop integrated management strategies.

Objective 2. *Xylella fastidiosa* colonization of grapevines and the role of overwinter recovery in Pierce's disease epidemiology.

Objective 3. Determine the role of spittlebug insects as vectors of *Xylella fastidiosa*.

Objective 4. Data mine and disseminate existing information on vector ecology, vegetation management, and efficacy of pruning.

Objective 5. Develop a larger extension and outreach footprint with additional seminars, extended interviews made available on the web, and an update to the *Xylella fastidiosa* website, the main online resource for PD information.

Results and Discussion

Vector, pathogen, and host community surveys

Thirty-two vineyard blocks, divided equally between Napa and Sonoma counties, were selected as study sites. Beginning in late February 2016, yellow sticky traps were deployed in either a transect or grid pattern in each study block such that between 4 and 12 traps were deployed at each location. In addition between 1 and 3 vegetation traps were deployed at each location adjacent to the putative source of blue-green sharpshooters (BGSS, mostly riparian vegetation). Traps were checked every 14 days in the spring, summer and fall and once a month in winter. Presence of vectors (mainly BGSS) was recorded. Insect vectors were also monitored on two-week intervals using sweep nets. Ground vegetation was sampled in the spring, summer and fall, and grapevine canopies were sampled in summer and fall only. BGSS were collected from the canopy, green and red-headed sharpshooters from grasses in the row middles, and spittlebugs (*Philaenus spumarius* and *Aphrophora sp*.) from both the canopy and the ground vegetation.

Beginning in late August and continuing through mid-September in 2016 and 2017, incidence of PD was recorded for each vine in all study blocks. Disease incidence was based on the occurrence of a combination of the common visual symptoms of PD: shriveled clusters, leaf scorching, uneven lignification of shoots, matchstick petioles and stunted growth. Two hundred samples were collected from Napa and Sonoma counties, respectively (n=400), to correlate visual assignment of vines as PD-positive with *X. fastidiosa* PCR-based detection in the laboratory (ongoing). Researchers walked every row of each block and recorded incidence of PD symptoms for individual vines on vineyard block maps. These maps were generated using Geographic Information Systems (GIS) to digitize a matrix of points in a spatial environment where each point represents a vine in its exact geographic location. A customized geoprocessing tool was created to generate detailed vine-by-vine GIS files with accurate row and vine spacing. Based on the inputs, the tool generates a new GIS point shapefile representing vine locations within a vineyard block. Data on disease incidence, missing vines, replants and dead vines was recorded (Table 1). In Sonoma County, incidence of PD symptoms ranged from 1.5 to 33.5% in 2016 and from 0.3% to 28.1% in 2017. In Napa County, incidence ranged from 0.09% to 22.4% and 0.06% to 7.8% in 2016 and 2017, respectively. A portion of replant and missing vines may be due to Pierce's disease in previous years. Spatial analysis of the georeferenced data is ongoing.

Table 1. Percent vines with Pierce's disease, replanted, missing and dead for 2016 and 2017 in 32 study blocks in Napa and Sonoma counties.

				Percent vines:			
County	Vineyard	Variety	Acres	PD	Replant	Missing	Dead
Napa	NA 2016	Cabernet Sauvignon	9.07	0.1	0.1	1.1	
	NA 2017			0.2	1.3	0.03	
	NB 2016	Chardonnay	5.0	0.04		70.3	
	NB 2017			22.4	0.03	45.4	0.04
	NC 2016	Merlot	3.03	0.09	2.2	4.2	0.09
	NC 2017			0.06	9.7		
	ND 2016	Cabernet Franc	6.37	2.9	13.1	0.03	0.05
	ND 2017			1.6	12.1	3.4	0.04
	NE 2016	Cabernet Sauvignon	7.44	0.2	10.8	0.1	
	NE 2017			0.1	7.5	0.1	
	NF 2016	Cab. Sauvignon	1.92	0.6	14.3	0.5	0.04
	NF 2017			0.3	11.6	3.6	
	NG 2016	Petit Verdot	0.89	0.9	10.7	9.7	0.1
	NG 2017			0.1	13.8	1.0	
	NH 2016	Cabernet Sauvignon	2.84	1.4	19.0	0.4	
	NH2017			0.2	13.2	0.5	0.04
	NI 2016	Cabernet Franc	2.5	1.5	7.3	0.1	
	NI 2017			2.7	7.1	0.2	
	NJ 2016	Cabernet Sauvignon	4.88	9.3	0.2	3.6	0.3
	NJ 2017			6.7	0.2	3.9	0.1
	NK 2016	Chardonnay	4.6	3.0	19.3	0.1	
	NK 2017			3.2	12.6	0.1	
	NL 2016	Malbec	1.69	0.2	2.6	3.5	0.1
	NL 2017			0.2	2.7	3.7	0.1
	NM 2016	Cabernet Sauvignon	4.42	0.5	0.3	1.2	0.2
	NM 2017			0.6	0.7	0.9	0.4
	NN 2016	Chardonnay	2.6	4.7	2.9	0.2	
	NN 2017			7.8	2.8	0.1	0.1

	NO 2016 NO2017	Cabernet Sauvignon	5.0	10.3 6.9	44.0 52.8	0.02 0.2	 0.04
	NP 2016 NP 2017	Cabernet Sauvignon	7.33	5.6 0.99	8.1 14.8	0.6 0.6	0.6 0.2
Sonoma	SA 2016 SA 2017	Chardonnay	5.1	17.2 3.8	11.1 18.8	0.2 0.7	1.8 2.1
	SB 2016 SB 2017	Chardonnay	5.45	7.0 10.2	0.6 0.6	0.0 5.0	0.1 0.1
	SC 2016 SC 2017	Zinfandel	1.1	1.7 0.8	28.8 23.9	0.5 1.8	3.2 3.6
	SD 2016 SD 2017	Zinfandel	4.3	7.0 5.0	0.0 0.0	1.1 1.5	3.0 2.5
	SE 2016 SE 2017	Chardonnay	3.8	6.4 NA	0.4 NA	3.7 NA	0.5 NA
	SF 2016 SF 2017	Gruner Veltliner	4.93	15.3 14.8	3.9 3.2	0.3 0.3	0.1 0.0
	SG 2016 SG 2017	Merlot, Cab. Sauv.	5.8	12.9 9.6	5.2 7.9	0.0 0.9	0.7 0.5
	SH 2016 SH 2017	Pinot Noir	3.97	33.5 28.1	5.9 14.8	0.0 0.0	0.0 0.1
	SI 2016 SI 2017	Merlot	3.8	1.5 0.3	15.6 9.4	0.1 1.1	0.5 0.4
	SJ 2016 SJ 2017	Chardonnay	7.5	5.9 1.6	17.7 12.2	0.0 0.0	0.0 0.1
	SK 2016 SK 2017	Malbec	4.25	20.1 15.4	7.6 7.6	0.1 0.9	0.0 1.4
	SL 2016 SL 2017	Chardonnay	2.25	3.6 6.0	0.2 24.2	20.5 0.0	0.5 0.0
	SM 2016 SM 2017	Chardonnay	5.0	22.9 11.2	4.2 3.7	0.0 3.2	1.0 0.0
	SN 2016 SN 2017	Chardonnay	4.2	8.4 8.9	12.7 7.2	0.0 0.2	0.1 0.5
	SO 2016 SO2017	Chardonnay	4.1	8.6 10.2	6.9 2.3	0.0 0.0	0.0 0.2
	SP 2016 SP 2017	Chardonnay	2.8	18.7 7.7	2.6 14.0	0.0 2.5	0.0 0.1

Vector monitoring

The BGSS monitoring program indicates vector populations in vineyards are low, with the highest densities primarily in some Sonoma County vineyard blocks between the end of March and mid-May (Figure 1). The leafhoppers species *Draeculacephala minerva*, *Pagaronia* sp., and the spittlebug species *Philaenus spumarius*, and *Aphrophora* sp. were collected from sweeping vegetation at the edge of some vineyard blocks and the leafhopper *Carneocephala fulgida* from Bermuda grass, *Cynodon dactylon* (Figure 2). These vectors were previously reported from this area (Delong & Severin, 1949; 1950). However, few studies have been done on the role these species may play in the spread of the pathogen.

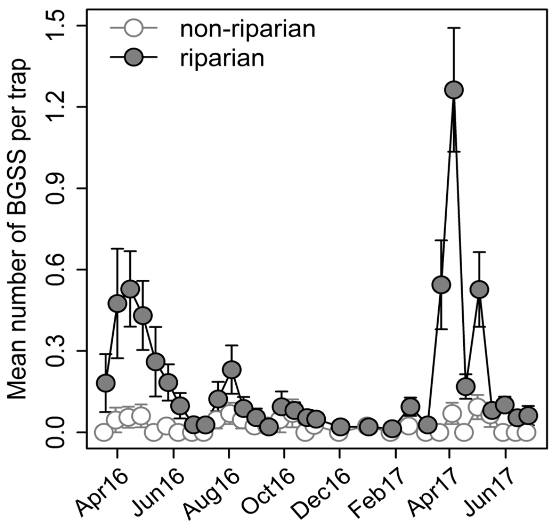

Figure 1. Mean number of BGSS caught on yellow sticky traps in 15 blocks in Sonoma County placed a) at the vineyard edge next to riparian vegetation (riparian) and b) inside the vineyard (non-riparian), from April 2016 through June 2017.

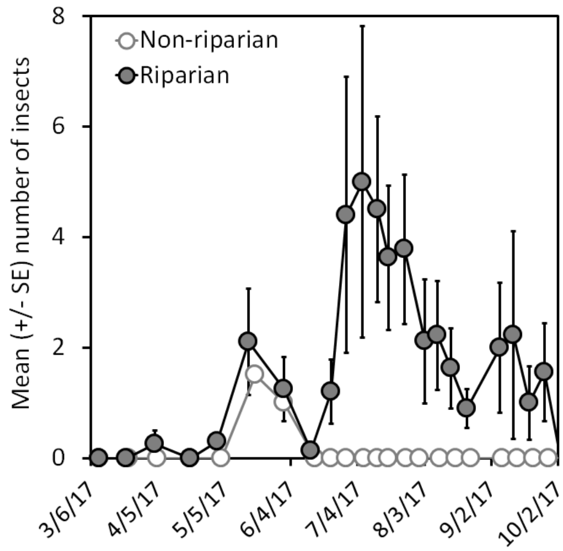

Figure 2. Mean number of vectors (all taxa) collected with sweep nets in 15 blocks in Sonoma County from March to October 2017. "Riparian" are sweeps performed on ground vegetation at the edge of the vineyard adjacent to the riparian vegetation. "Non-riparian" are sweeps taken on the ground vegetation and the canopy inside the vineyard.

Estimating the importance of climatic conditions for driving PD incidence

As a first step toward understanding whether climatic conditions in recent years have contributed to the ongoing PD resurgence in the North Coast, we compared historic data from 11 weather stations from throughout the grape-growing regions of Napa and Sonoma counties, which include up to 70 years of data. All else being equal, a lack of cold conditions over the winter and early spring should contribute to PD incidence, by reducing the fraction of vines recovering from infection (Feil and Purcell 2001) and potentially contributing to greater vector population densities (Gruber and Daugherty 2012). To address this prediction, we compared historic averages with more contemporary observed dormant season (i.e. November through April) temperatures between 2011 and 2016, focusing on two metrics: 1) mean daily minimum temperature and 2) number of days with winter temperatures below 4.4^{o}C (Lieth et al. 2011).

For each of the 11 sites, we calculated historic averages for both of the temperature metrics, and the corresponding values for each of the seasons between 2011 and 2016 – a span of time that conservatively captures the onset of the most recent PD epidemic in the North Coast. Next, to facilitate comparisons among sites, the contemporary year estimates were standardized by dividing by the historic average for that site. Thus, values of relative daily minimum temperature greater than 1 correspond to a dormant season that is warmer than the historic average, whereas values of the relative frequency of days with minimum temperatures below 4.4^{o}C of greater than 1 indicate conditions colder than the historic average.

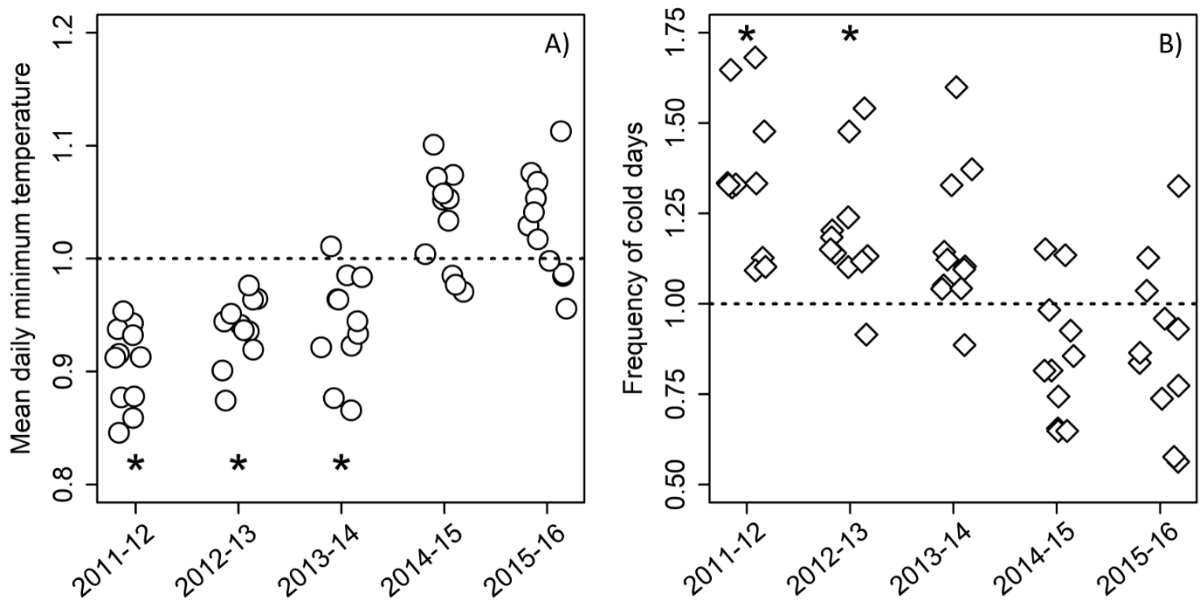

Figure 3. Relative A) daily minimum temperature and B) number days with minimum temperatures below 4.4^{o}C over the dormant season (November – April) compared to historic averages at 11 sites in Napa and Sonoma counties. * denote yearly means that are significantly different than the historic average.

Conclusions

In 32 study blocks in Sonoma and Napa counties disease incidence range from 0.1 to 33.5% in 2016 and 2017. Both metrics of dormant season temperatures show significant trends between 2011 to 2016. However, there is not compelling evidence that these contemporary seasons were warmer overall compared to historic observations. With respect to daily minimum temperature (Figure 3A), after controlling for multiple comparisons, the first three seasons were significantly colder than the historic average, and the last two seasons were not significantly different from the historic average. Similarly, with respect to the frequency of days with minimum temperatures below 4.4^{o}C, the first two seasons had significantly more cold days than the historic average, and the last 3 seasons were not significantly different from the historic average. In other words, if anything, conditions were unusually cold in the first 3 seasons and were approximately average the last two years. The next step in our assessment of the potential for climate to have triggered the current PD epidemic in the North Coast will be to consider other metrics of dormant-season and growing-season temperatures, and patterns of precipitation.

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Funding Agencies
Funding for this project was provided by the CDFA PDCP program (#15-0453-SA).