PROGRESS OF PIERCE'S DISEASE IN THREE *VITIS VINIFERA* SCIONS GRAFTED ON THREE ROOTSTOCKS

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ABSTRACT
We are documenting Pierce's disease (PD) progress, vigor, and bud break dates in selected *Vitis vinifera* scion x rootstock combinations. Own-rooted 'Chardonnay,' 'Merlot,' and 'Cabernet Sauvignon' (checks) and these scions grafted in all combinations on Freedom, Paulsen 1103, and Dog Ridge were established at Uvalde and Stonewall, TX in 2009. Selected border plants at Uvalde were inoculated with the PD bacterium (*Xylella fastidiosa* subsp. *fastidiosa*) 10-11May2010 and insecticide was not used. There was no inoculation or insecticide in plots at Stonewall but imidacloprid was injected through drip irrigation on adjacent established vines for control of glassy-winged sharpshooter (GWSS) and other vectors. Incidence of early-stage PD was 81% by 10Sep2010 at Uvalde but near 0% at Stonewall 26Aug2010. Scion accounted for more or similar proportions of variability of variables compared to rootstock. There were several significant low level scion x rootstock interactions. We expected scions to hold up the best on Dog Ridge, but Paulsen 1103 looked better for PD and vigor in September of the second-leaf vines at Uvalde. We attribute the higher-than-anticipated PD incidence to inoculation of border Chardonnay plants and high GWSS populations which facilitating vector acquisition. GWSS was the predominant vector species, and adult and nymph numbers were high for several weeks. Rootstocks most delayed bud break on Chardonnay. Evaluations of both plantings will continue, with fruiting in 2011.

LAYPERSON SUMMARY
Two ongoing vineyard trials explore rootstock effects on Pierce's disease (PD) in Gillespie and Uvalde Counties in Texas. While all *Vitis vinifera* scions are considered susceptible to *Xylella fastidiosa* subsp. *fastidiosa*, the bacterium that causes PD, there are noticeable differences in timing of symptom expression. On 10Sep2010, 'Cabernet Sauvignon' had less severe symptoms but the greatest incidence and ELISA optical density (OD) reading in positive plants compared to 'Merlot' and 'Chardonnay.' In Texas where late spring freezes often occur, Chardonnay is unsuited due to early bud break, severe PD symptoms soon after infection, and ultimate death. At the high vigor Uvalde site, all three rootstocks somewhat delayed bud break date and increased vigor, vine diameter, and leaf color (before Fe supplementation) compared to own-rooted scions. To date, Paulsen 1103 rootstock provided more PD and vigor benefits than Dog Ridge. Freedom has inefficient Fe uptake in the high pH soil and requires aggressive Fe supplementation for green leaf color. At the moderate vigor Stonewall site, essentially no PD has occurred and Fe uptake is not limiting.

INTRODUCTION
There is anecdotal evidence in Texas that progress of Pierce's disease (PD), caused by *Xylella fastidiosa* (*Xf*) subsp. *fastidiosa*, differs among *Vitis vinifera* scions (e.g., 'Chardonnay'>'Merlot'>'Cabernet Sauvignon'). PD symptom severity and vine mortality are apparently greater under environmental stresses, including over-cropping. Rootstocks are used to overcome environmental stresses and can affect vine vigor and fruit load. In a previous 3-year study we found that 12 ungrafted rootstocks commonly used in Texas had PD reactions ranging from vine mortality to mild leaf scorch symptoms. More information is needed on rootstock effects on scion PD symptom development (3), vine growth, and productivity. This study compares PD progression in *Vitis vinifera* scions (representing a limited range of PD progress rates) grafted on rootstocks previously shown to exhibit severe, intermediate, and mild PD reactions. Both vineyards will be allowed to fruit in 2011 and crop load potential will be adjusted according to pruning weights. Evaluations will continue as vines at both sites experience winter cold, spring pruning, fruit load stress, and PD vector activity.

OBJECTIVES
1. Document scion x rootstock effects on progress of PD, vigor, and bud break date.

RESULTS AND DISCUSSION

Chardonnay, Merlot, and Cabernet Sauvignon were omega-grafted, callused, and rooted in spring 2008 in all combinations with rootstocks we previously showed had severe (Freedom, interspecific cross includes *V. labrusca*, *V. riparia*, *V. champinii*, *V. vinifera*) (1), intermediate (Paulsen 1103, *V. berlandieri* x *V. rupestris*), and mild (Dog Ridge, *V. champinii*) PD symptoms. Dormant virus-tested scion and rootstock wood was procured for propagation (Foundation Plant Services, University of California, Davis).

Treatments (3 scions x 3 rootstocks) and controls (own-rooted scions) were established in 2009. Sites near Stonewall, TX (Gillespie County, pH 6.5, PD history, imidacloprid use in adjacent vineyard block, Malbec/Paulsen 1103 border) and Uvalde (Uvalde County; pH 8.3; no vineyard nearby; own-rooted Chardonnay in a mixed border; adjacent to citrus, piñon pine and other ornamentals used by GWSS) had five replications and five plants per plot. Plants in first-leaf (2009) had no definite symptoms, and rare ELISA positive reactions (optical density, OD≥0.300) in leaf samples biased towards PD symptoms (Stonewall 1% 24Aug09, 0% 27Oct09; Uvalde 0% 31Aug09, 1% 16Nov09). Borders at Stonewall were not inoculated and GWSS feeding was probable but not observed. Stonewall plots and borders had no definite symptoms on 26Aug2010 and symptom-biased leaf samples had 0% ELISA positives. Own-rooted Chardonnay new growth in the Uvalde border was twice inoculated 10-11May2010 with *Xf* winegrape isolate GIL BEC 625 and glassy-winged sharpshooter (GWSS) feeding activity occurred for >5 months. PD symptoms at Uvalde developed first in borders then in many plots. All Uvalde plants received soil drenches and foliar sprays of Fe and other minor element supplements with extra applications for own-rooted and Freedom treatments.

We emphasize Uvalde main factor effects in this report (**Tables 1, 3**), although five parameters had low level significant scion x rootstock interactions. Scion choice accounted for the most variability (compare MS values) of six parameters in 2010 (**Table 2**). Growth stage and pruning weights at Stonewall had similar responses (data not presented).

Late summer 2010 ELISA tests were all negative at Stonewall but 81% positive for *Xf* at Uvalde where PD symptoms overall mean (including own-rooted checks) was 6% leaves (Table 1). Consistent with previous observations in young plantings, Cabernet Sauvignon had less severe PD symptoms than Merlot and Chardonnay, but Cabernet Sauvignon had the most positive plants and highest mean OD values (Tables 1,3). Perhaps *Xf* numbers peak and collapse sooner in infected Chardonnay than in Merlot and Cabernet Sauvignon.

Table 1. Responses in 2010 of three *V. vinifera* cultivars own-rooted and grafted on three rootstocks at Uvalde, TX adjacent to GWSS refuges where selected border plants were inoculated with *Xf* and imidacloprid insecticide was not used for sharpshooter control.

Scion	Rootstock	Pruning wt., g[a]		Vine dia., mm[b]		Canopy color[c]		PD symptoms[d]		Positive, %[e]		Positive plants OD[f]	
'Chardonnay'	Own	119	f[g]	9	g	1.5	g	9.4	de	49	a	1.291	bcd
'Chardonnay'	Dog Ridge	382	ab	14	cd	2.7	ab	11.4	e	81	cde	1.157	abc
'Chardonnay'	Freedom	293	c	13	def	2.7	ab	4.8	ab	66	abc	1.035	a
'Chardonnay'	Paulsen 1103	434	a	15	c	2.9	a	5.8	abc	83	cde	1.162	abc
'Merlot'	Own	52	h	8	g	2.4	cd	7.0	bcd	61	ab	1.214	abcd
'Merlot'	Dog Ridge	156	e	12	f	2.4	cde	7.8	cde	97	de	1.106	ab
'Merlot'	Freedom	114	f	11	f	2.4	cde	7.4	bcd	93	de	1.071	ab
'Merlot'	Paulsen 1103	198	d	13	cde	3.0	a	6.2	bcd	69	bc	1.013	a
'Cabernet Sauvignon'	Own	80	g	12	ef	2.3	de	5.0	abc	98	e	1.349	cd
'Cabernet Sauvignon'	Dog Ridge	397	ab	19	a	1.9	f	4.6	ab	97	de	1.264	bcd
'Cabernet Sauvignon'	Freedom	179	de	16	bc	2.1	e	3.5	a	100	e	1.369	cd
'Cabernet Sauvignon'	Paulsen 1103	333	bc	17	b	2.5	bc	3.5	a	77	bcd	1.401	d

[a]Pruning weights 2April2010. Days-after-planting was significant covariate. Data were transformed ($\log_{10}$ y) before analysis. De-transformed least squares means (10^x) are geometric means.

[b]25Feb2010 at 10 cm above graft union or equivalent for own-rooted.

[c]1=chlorotic, 2=intermediate, 3=green on 10Sep2010; wind damage was significant covariate; least squares means.

[d]Percent leaves with PD symptoms including scorched and defoliated ,10Sep10. Data were transformed (square root (y+0.5)) before analysis. De-transformed least squares means (x^2 + error mean square) are presented here.

[e]Percent plants *Xf*-positive with ELISA (optical density ≥0.300) from 10Sep2010 leaf samples biased towards PD symptoms.

[f]OD means for *Xf*-positive plants only.

[g]Means followed by the same lower case letter were not significantly different (P≤0.05); least squares means, PDIFF option.

More scion PD symptoms on Dog Ridge than Freedom and Paulsen 1103 rootstocks was unexpected, as was the high PD incidence in scions on Dog Ridge (90%, based on ELISA tests) (**Table 3**). Once infections crosses the graft union, Freedom is expected to succumb to PD. Dog Ridge rootstock sustained new scion growth into late summer on several plants, and infected GWSS may have preferred feeding on that new growth, allowing *Xf* to increase in the new scion growth.

Cabernet Sauvignon and Chardonnay had greater pruning weight than Merlot (**Table 3**). Cabernet Sauvignon had greater vine diameter than Chardonnay, and Merlot had less vine diameter than the other two scions. Freedom had less pruning weight and vine diameter than Dog Ridge and Paulsen 1103. Rootstock explained more variability in vine diameter than in pruning weight (**Table 2**).

Spring freezes in April are a frequent problem in Texas and growers need information on practices that affect bud break date. Pruning after bud break is used for some scions and locations. At Uvalde, Chardonnay began growth very early, as expected (E-L growth stage 3 woolly bud 23-27Feb10) (**Figure 1**). Merlot and Cabernet Sauvignon had similar growth stage at 22Mar10, then Merlot accelerated (E-L3 22-24Mar10) compared to Cabernet Sauvignon (E-L3 28Mar-10Apr10). Rootstocks somewhat delayed growth stage compared to own-rooted vines of all scions, but scion had far more effect on growth stage date than rootstock. Paulsen 1103 delayed Chardonnay E-L5 about 1 week. It is widely recognized that this rootstock effect is highly specific to scion.

Own rooted plants at Uvalde mostly had low vigor, pruning weight, and vine diameter, and poor leaf color (even with additional Fe supplements) as expected due to high soil pH (**Table 1**). September chlorotic canopy in Cabernet Sauvignon and Dog Ridge may be related to propensity for prolonged vegetative growth after the last Fe application during summer stress which can reduce Fe uptake. On 10Sep10, Paulsen 1103 had the best green canopy color (**Table 3**). Poor plant condition probably reduced GWSS adult feeding, and this may explain less PD in Chardonnay. Freedom rootstock had more early-season chlorosis in 2009 and 2010 than Dog Ridge and Paulsen 1103, but Freedom eventually responded to extra Fe supplements.

CONCLUSIONS

Benefits from rootstocks are apparent in second-leaf at both Uvalde and Stonewall including vigor, a slight delay in bud break, and tolerance of high pH limestone-based soils (**Tables 1,3**). Rootstocks had some effects on PD in second-leaf at Uvalde. ELISA OD was quite high even for mild PD symptoms in Cabernet Sauvignon, reminiscent of reports for native American hybrid scions. Own-rooted *V. vinifera* cultivars are clearly not adapted at Uvalde (**Table 1**), where own-rooted and Freedom treatments received more iron supplements from late winter through early summer than other treatments. Vigor and chlorosis differences may have influenced PD insect vector usage among plants at Uvalde. Significant GWSS refuges at the Uvalde site where PD increased dramatically highlight the importance of site selection, vegetation management near vineyards, and sharpshooter control. Nearby sources of *Xf* are very dangerous for vineyards with *V. vinifera* scions, and rapid PD development at Uvalde points to the need for early detection and vigorous roguing in highly susceptible cultivars. Imidacloprid used adjacent to the Stonewall site suppressed GWSS and other xylem-feeding vectors in 2010, providing impetus for trap crop experiments. We will continue evaluations in late fall 2010 and beyond.

Table 2. Sources of variance in 2010 of three *V. vinifera* cultivars grafted on three rootstocks (own-rooted checks data deleted) at Uvalde, TX adjacent to GWSS refuges where selected border plants were inoculated with *Xf* and imidacloprid insecticide was not used for GWSS control.

		Pruning wt, g[a]		**Vine dia., mm**[b]		**Canopy color**[c]		**PD sympt.**[d]		**Positive**[e]		**Pos. plants OD**[f]	
Source of variance[g]	df	MS[h]	Pr > F	MS	Pr > F	MS	Pr > F	MS	Pr > F	MS	Pr > F	MS	Pr > F
Replication	4	0.07	0.0093	52.1	0.0003	0.69	0.0139	1.4	0.2781	25	0.0643	0.34	0.0211
Scion	2	2.74	0.0001	303.5	0.0001	7.55	0.0001	16.6	0.0001	49	0.013	1.41	0.0001
Rootstock	2	0.14	0.0009	163.7	0.0001	5.13	0.0001	8.6	0.0004	46	0.0161	0.01	0.8854
Scion x rootstock	4	0.06	0.0208	44.3	0.0013	0.55	0.0406	2.8	0.0371	40	0.0074	0.12	0.4101
Days-after-planting	1	0.11	0.0207							208	0.0001		
Wind damage	1					8.09	0.0001					0.57	0.028
Total df		206		207		224		224		224		118	

[a]Pruning weights 2April2010. Data were transformed ($\log_{10}$ y) before analysis.
[b]25Feb2010 at 10 cm above graft union or equivalent for own-rooted.
[c]1=chlorotic, 2=intermediate, 3=green 10Sep2010.
[d]Percent leaves with PD symptoms (scorching, defoliation) 10Sep2010; data transformed (square root (y+0.5)) before analysis.
[e]Percent plants positive for *Xf* with ELISA (OD ≥0.300) from 10Sep2010 leaf samples biased towards PD symptoms.
[f]Negative plants were omitted for optical density analysis.
[g]Single df indicate significant covariates used to adjust least squares means.
[h]Mean square from PROC GLM.

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Table 3. Responses in 2010 of three *V. vinifera* cultivars grafted on three rootstocks (own-rooted checks data deleted) at Uvalde, TX adjacent to GWSS refuges where selected border plants were inoculated with *Xf* and imidacloprid insecticide was not used for GWSS control. Scion x rootstock interactions were significant (P<0.05) for all variables (data not presented).

Factor	Pruning wt, g[a]		Vine dia, mm[b]		Canopy color[c]		PD symptoms[d]		Positive, %[e]		Positives OD[f]	
Scion												
'Chardonnay'	354	a[g]	14	b	2.8	a	6.7	b	75	a	1.113	a
'Merlot'	147	b	12	c	2.6	b	6.7	b	85	ab	1.061	a
'Cabernet Sauvignon'	336	a	16	a	2.2	c	3.5	a	92	b	1.340	b
Rootstock												
Dog Ridge	277	a	15	a	2.3	b	7.3	b	90	b	1.173	
Freedom	211	b	12	b	2.4	b	4.7	a	87	ab	1.155	
Paulsen 1103	299	a	15	a	2.8	a	4.7	a	75	a	1.186	

[a]Pruning weights 2April2010; analysis on transformed ($\log_{10}$ y) data; de-transformed least squares means (10^x) are geometric means.
[b]25Feb2010 at 10 cm above graft union or equivalent for own-rooted.
[c]1=chlorotic, 2=intermediate, 3=green on 10Sep2010.
[d]Percent leaves with PD symptoms (scorching, defoliation) 10Sep2010; analysis on transformed (square root (y+0.5)) data; de-transformed least squares means (x^2 + error mean square) are presented here.
[e]Percent plants *Xf*-positive with ELISA (OD ≥0.300) from 10Sep2010 leaf samples biased towards PD symptoms.
[f]Negative plants deleted from analysis.
[g]Means followed by the same lower case letter were not significantly different (P≤0.05); least squares means, PDIFF option.

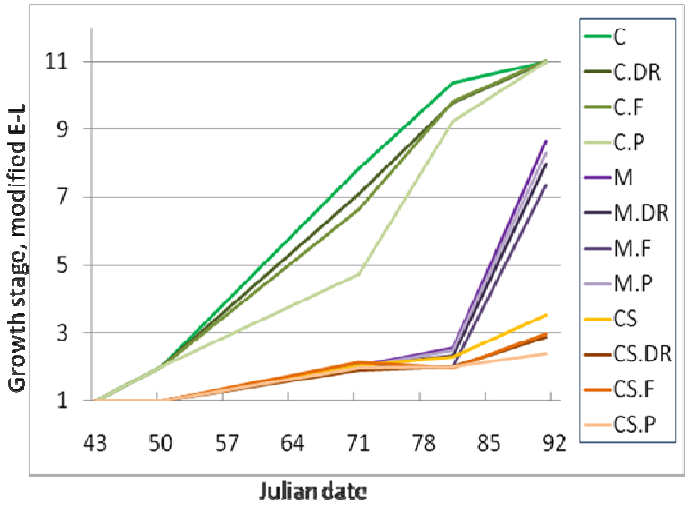

Figure 1. Second leaf early season growth stages at Uvalde, TX for 'Chardonnay' (C), 'Merlot' (M), and 'Cabernet Sauvignon' (CS) own-rooted and grafted on Dog Ridge (DR), Freedom (F), and Paulsen 1103 (P). Data are the greatest growth stage (modified E-L system, 5=rosette of leaf tips visible) anywhere on a plant. Observations Julian (and calendar) dates were 43(12Feb), 50 (19Feb), 71 (12Mar), 81 (22Mar), and 91 (1Apr2010).