**Objectives**

1. Breed PD resistant winegrapes through backcross techniques using high quality *V. vinifera* winegrape cultivars and *Xf* resistant selections and sources characterized from our previous efforts.

2. Continue the characterization of *Xf* resistance and winegrape quality traits (color, tannin, ripening dates, flavor, productivity, etc) in novel germplasm sources, in our breeding populations, and in our genetic mapping populations.

**Results**

Objective 1 The breeding cycle for the development of PD resistant grapes has been reduced to three years (seed to seed) using marker-assisted selection (MAS) with the b43-17 resistance sources and their progeny. The 2006 crosses, number of seedlings produced and the number of seedlings that went to the field are presented in the 2006 Proceedings and in March 2007 Report. Our goal at this point is to introgress our PD and PdRI resistance sources into a large number of *V. vinifera* winegrapes backgrounds. Until we get to the backcross 4 (BC4) (96.8% *V. vinifera*), there is not much point to growing very large numbers of progeny from any given cross. With the now standard three-year seed-to-seed cycle we will plant BC4 progeny in 2010.

Table 1 presents the crosses made and seed produced in 2007. The goals of this year’s crosses were to: 1) Use the PdRI allele from the 8909-08 to make 93.75% *vinifera* level progeny; 2) Broaden the *vinifera* winegrape lines in the 8909-08 resistance source at the 87.5% *vinifera* level; 3) Combine PdRI with the powdery mildew resistance gene Run1 at the 87.5% *vinifera* level; 4) Use 8909-17 and 8909-08 based resistance with diverse *vinifera* winegrapes to produce resistant progeny at the 87.5% *vinifera* level; 5) Use the 8909-15 resistance source with a broad range of *vinifera* winegrapes; and 6) Produce rootstocks with PdRI and broad-based nematode resistance.

Five groups of plants were greenhouse screened for *Xf* resistance in 2007. Group A tests (160 genotypes) were done to verify the expression of PdRI from b43-17 in the 04190 (*V. vinifera* F2-7 x 8909-08) population, and confirm PdRI in parents used in 2006. The Group B tests (76 genotypes) examined progeny of Midsouth and BD5-117 crossed to advanced *vinifera* wine
types. Both of these parents continue to produce resistant progeny, but very few and in ratios that suggest a complex inheritance. The progeny of Haines City (n=9) were all resistant by ELISA in the greenhouse screen, but do not contain PdR1. Eleven genotypes from Olmo's e-series BC2 that carry Runl (the powdery mildew resistance marker) were also tested, none were resistant and they seemed more sensitive to PD than typical vinifera. Group C tested the use of b43-17 as a rootstock and interstock to examine Xf transmission and expression through a graft union. b43-17 did not induce PD resistance in Chardonnay, but preliminary results found that it and A8909-05 (V. rupestris x M. rotundifolia) prevented PD expression in Chardonnay scions when they were used as interstocks. Group D tests (120 genotypes) focused on mapping population progeny to verify recombinants and establish resistance ratios. Recombinants from 04190 were tested and aided fine-scale PdR1 mapping efforts; three recombinants from the 04191 (vinifera F2-7 x 8909-17) were also tested. The 05347 population (vinifera F2-35 x V. arizonica b42-26) was also tested (n=60) to establish the R/S ratios derived from b42-26, which is quantitatively inherited and provides an alternative and strong source of PD resistance. Progeny from these tests will be used for mapping studies and as parents with a non-PdR1 resistance. Group E tests (150 genotypes) included additional 04190 progeny and remnants from the 9621 (8909-15 x 8909-17) that had not been tested. This group also tested advanced PdR1 carrying parents, which were used in the 2007 crosses based on marker data alone, to confirm their resistance.

Objective 2 Although resistance from other backgrounds is complex and quantitative, which results in few resistant progeny from crosses to vinifera cultivars, we continue to advance a number of lines. In order to better understand the limits of other PD resistance sources the following resistance sources are being studied:

V. arizonica b42-26 – Xf resistance in the 0023 (D8909-15 V. rupestris x b42-26) x vinifera B90-116) population is strong, but is quantitatively inherited. Quantitative trait locus (QTL) analysis has identified a major QTL that accounts for about 20% of the variability (preliminary results). Previous efforts with the 0023 were focused on table grape breeding, and found that the 0023 population (F1, 1/4 b42-26) had about 30% resistant progeny. This population has a large number of weak genotypes, few females with viable seeds, and generally lacks fertility. The progeny of a cross of a resistant 0023 genotype crossed back to vinifera (BC1) were tested and only 7% were resistant. We are now testing 05347 (vinifera F2-35 x b42-26) to examine the b42-26 resistance source in a less complex background (without the confounding effect of V. rupestris). Crosses using elite V. vinifera wine type pollen were made to a number of females in this population in Spring 2007 (Table 1f).

V. arizonica b40-14 – In 2006 we crossed F2-35 x b40-14, produced 1,385 seeds and established 198 seedlings for testing. We are planning on using this population, or one generated from its progeny for mapping efforts to better characterize this very strong, and morphologically and genetically different source of PD resistance (Table 1f).

Field and Wine Evaluations The A81 series (BC1, 75% vinifera) F8909-08 allele type of PdR1 is in its second year of field testing at the Beringer Yountville test site; ELISA and visual symptom results have been consistent with greenhouse assays. Selections from the 045554 (BC2, 88% vinifera) have been made onto Dog Ridge (currently the only certified PD resistant rootstock) and were planted at Yountville on May 14, 2007. These genotypes have been marker tested and their PD resistance status confirmed by greenhouse testing. Twelve genotypes were resistant, four were recombinants (one resistant and three susceptible in the greenhouse test). They will be inoculated in Spring 2008.

Three of eight advanced red wine selections (U0501-12, U0502-01 and -10) containing PdR1 that are 87.5% vinifera from crosses with Syrah and Chardonnay were replicated for small-scale fermentation this Fall. About four liters of wine from each were produced along with similar amounts of Cabernet Sauvignon and Pinot noir as V. vinifera controls and Midsouth and Lenoir as standard PD resistant controls. These selections were evaluated for their productivity, flowering and ripening dates, and berry and cluster weights. Vine, fruit and juice analyses are presented in Tables 2a, 2b and 2c, and images of the leaves and fruit are in Figure 1.

Numerous other genotypes from crosses involving elite vinifera wine cultivars were examined for fruit evaluation and must analysis. ETS Laboratories (www.etslabs.com) of St. Helena kindly donated their fruit analysis and phenolics panel, which uses a wine-like extraction to model a larger fermentation. Surprisingly, none of the U05 series analyzed contained significant levels of diglucoside anthocyanins, which are negative quality markers for hybrid wines with American grape species and which would create problems with exporting wines to the EU. Cuttings of the best of these will be taken in the winter so that we can get small-scale wine lots made for evaluation in 2009. Plants will be grown in both Davis and Napa when possible. A new MS student is examining the reasons for the lack of diglucoside anthocyanins in these selections to determine whether the arizonica-resistance sources possess these anthocyanins. A second MS student is in the second year of examining what wine quality parameters are useful at micro (2L), mini (20L) and macro (2,000L) scales. Determining how to best select for wine quality at the micro scale will be critical as we begin to evaluate large populations of PD resistant and 96% vinifera selections.
Powdery Mildew - Any new PD resistant variety should also be resistant to powdery mildew. We have been exploring powdery mildew resistance in a number of backgrounds including Olmo’s VR (v. x rotundifolia) hybrids, which form the base of international efforts at characterizing Run1, the rotundifolia-based locus responsible for resistance to powdery mildew. Current season field evaluations of the 2006 crosses show the markers correlating perfectly with field resistance on leaf and cane. Berry and cluster observations will begin in Fall 2008. The goal with these individuals is to cross our advanced PD resistant selections with selections from these powdery mildew resistant progeny. We also made crosses to examine powdery mildew in two other backgrounds, Villard blanc and Tamiami. Powdery mildew resistance markers are being developed for these resistance sources by labs in Germany and the US.

CONCLUSIONS
This project continues to breed PD resistant wine grapes with the primary focus on the PdR1 resistance source so that progress can be expedited with MAS. Populations with Xf resistance from other sources are being maintained and expanded, but progress is slower with these sources. We continue to supply plant material, conduct greenhouse screens and develop new mapping populations for our companion project on fine-scale mapping of PD resistance leading to the characterization of the PdR1 resistance. Fall 2007 will see the first testing of wine from advanced selections with 87.5% v. from wine grapes.

REFERENCES

FUNDING AGENCIES
Funding for this project was provided by the CDFA Pierce’s Disease and Glassy-winged Sharpshooter Board. Additional support from the Louis P. Martini Endowed Chair in Viticulture, and the donated wine analyses from ETS Labs, St. Helena are also gratefully acknowledged.

Figure 1. Pictures of the 87.5% v. PD resistant wine grape selections used for small-scale winemaking at UCD in 2007.
### Table 1. 2007 crosses and numbers of seed produced.

<table>
<thead>
<tr>
<th>Resistant Type</th>
<th>Vinifera Parent of Resistant Type</th>
<th>Vinifera Types used in 2007 crosses</th>
<th># Seeds Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a. Monterrey V. arizonica/candicans resistance source (F8909-08) to produce progeny with 93.75% V. vinifera parentage.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U0501</td>
<td>Syrah</td>
<td>F2-7, F2-35</td>
<td>478</td>
</tr>
<tr>
<td>U0502</td>
<td>Chardonnay</td>
<td>F2-7, F2-35</td>
<td>2,769</td>
</tr>
<tr>
<td>U0503</td>
<td>Sauvignon blanc</td>
<td>Chardonnay, Palomino, Semillon</td>
<td>126</td>
</tr>
<tr>
<td>U0505</td>
<td>Cabernet Sauvignon</td>
<td>Chardonnay, F2-7, LCC, Merlot, Palomino, Petite Syrah</td>
<td>3,229</td>
</tr>
<tr>
<td>1b. Monterrey V. arizonica/candicans resistance source (F8909-08) to produce progeny with 87.5% V. vinifera parentage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>05310</td>
<td>Alicante Bouschet</td>
<td>Burger, Carignane, LCC</td>
<td>1,666</td>
</tr>
<tr>
<td>05312</td>
<td>Cabernet Franc</td>
<td>Zinfandel</td>
<td>194</td>
</tr>
<tr>
<td>05317</td>
<td>Tempranillo</td>
<td>Burger, LCC</td>
<td>371</td>
</tr>
<tr>
<td>05319</td>
<td>Zinfandel</td>
<td>Cabernet Franc, LCC</td>
<td>144</td>
</tr>
<tr>
<td>A81-17</td>
<td>A38-7</td>
<td>Carignane, Grenache noir, LCC</td>
<td>705</td>
</tr>
<tr>
<td>1c. Monterrey V. arizonica/candicans resistance source (F8909-08) and Run1 powdery mildew resistance.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U0501, U0504</td>
<td>Syrah</td>
<td>e-series, e78 and e88 allele patterns</td>
<td>499</td>
</tr>
<tr>
<td>U0502</td>
<td>Chardonnay</td>
<td>e-series, e78 and e88 allele patterns</td>
<td>837</td>
</tr>
<tr>
<td>U0505</td>
<td>Cabernet Sauvignon</td>
<td>e-series, e78 and e88 allele patterns</td>
<td>642</td>
</tr>
<tr>
<td>A81-17</td>
<td>A38-7</td>
<td>e-series, e78 allele pattern</td>
<td>603</td>
</tr>
<tr>
<td>1d. Monterrey V. arizonica/candicans resistance source (F8909-08) and Vitis PM resistance source.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U0505, A81-17</td>
<td>Cabernet Sauv, A38-7</td>
<td>Villard blanc</td>
<td>348</td>
</tr>
<tr>
<td>1e. Monterrey V. arizonica/candicans resistance source (F8909-17 allele) to produce progeny with 75% V. vinifera.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>04373-02</td>
<td>F2-35 (Cab x Carignane)</td>
<td>Alicante Bouschet, Aligote, Carignane, Chardonnay, Zinfandel</td>
<td>597</td>
</tr>
<tr>
<td>04373-08</td>
<td>F2-35 (Cab x Carignane)</td>
<td>Aligote, Cabernet Franc, Carignane</td>
<td>938</td>
</tr>
<tr>
<td>04373-64</td>
<td>F2-35 (Cab x Carignane)</td>
<td>Grenache noir</td>
<td>293</td>
</tr>
<tr>
<td>1f. Other resistance sources. R89 is 50% vinifera, 25% resistance source. 05347 is 75% vinifera and 25% resistance source</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R89 (b40-14)</td>
<td>NR</td>
<td>Airen</td>
<td>238</td>
</tr>
<tr>
<td>05347 (b42-26)</td>
<td>F2-35</td>
<td>Aligote, Chardonnay, Grenache noir, Zinfandel</td>
<td>1,877</td>
</tr>
<tr>
<td>1g. Rootstock crosses to combine PD and nematode resistance.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9621-257</td>
<td>9365-85</td>
<td></td>
<td>653</td>
</tr>
<tr>
<td>9365-43</td>
<td>9621-161</td>
<td></td>
<td>112</td>
</tr>
</tbody>
</table>

### Table 2a. Phenotypic observations of reference varieties and select progeny with the PdR1 resistance source.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Parentage</th>
<th>Percent vinifera</th>
<th>2007 Bloom Date</th>
<th>Berry Color</th>
<th>Berry Size (g)</th>
<th>Ave Cluster Wt. (g)</th>
<th>Ripening Season</th>
<th>Prod 1=v low 9=vhig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cab. Sauv.</td>
<td>Cab. Franc x S. blanc</td>
<td>100%</td>
<td>5/20/07</td>
<td>B</td>
<td>1.0</td>
<td>168</td>
<td>mid-late</td>
<td>6</td>
</tr>
<tr>
<td>Pinot noir</td>
<td>Historic</td>
<td>100%</td>
<td>5/7/07</td>
<td>B</td>
<td>1.1</td>
<td>259</td>
<td>Early</td>
<td>6</td>
</tr>
<tr>
<td>U0501-12</td>
<td>A81-138 x Syrah</td>
<td>87.5%</td>
<td>5/7/07</td>
<td>B</td>
<td>1.0</td>
<td>90</td>
<td>mid-late</td>
<td>4</td>
</tr>
<tr>
<td>U0502-01</td>
<td>A81-138 x Chardonnay</td>
<td>87.5%</td>
<td>5/1/07</td>
<td>B</td>
<td>1.6</td>
<td>128</td>
<td>mid-late</td>
<td>4</td>
</tr>
<tr>
<td>U0502-10</td>
<td>A81-138 x Chardonnay</td>
<td>87.5%</td>
<td>5/1/07</td>
<td>B</td>
<td>1.4</td>
<td>160</td>
<td>very early</td>
<td>7</td>
</tr>
<tr>
<td>Lenoir</td>
<td>V. aestivalis hybrid</td>
<td>&lt;50%</td>
<td>5/12/07</td>
<td>B</td>
<td>0.8</td>
<td>201</td>
<td>Late</td>
<td>7</td>
</tr>
<tr>
<td>Midsouth</td>
<td>DGxGalibert 255-5</td>
<td>&lt;50%</td>
<td>5/5/07</td>
<td>B</td>
<td>2.2</td>
<td>211</td>
<td>mid-late</td>
<td>6</td>
</tr>
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</table>
**Table 2b.** Analytical evaluation of reference varieties and advanced selections with the *PdR1* resistance source. Diglucoside anthocyanins were detected in Midsouth and Lenoir. All analysis courtesy of ETS Laboratories, St. Helena, CA.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>L-malic acid (g/L)</th>
<th>°Brix</th>
<th>potassium (mg/L)</th>
<th>pH</th>
<th>TA (g/100mL)</th>
<th>YAN (mg/L as N)</th>
<th>catechin (mg/L)</th>
<th>tannin (mg/L)</th>
<th>Total anthocyanins (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cab. Sauvignon</td>
<td>2.19</td>
<td>24.9</td>
<td>2460</td>
<td>3.65</td>
<td>0.62</td>
<td>227</td>
<td>59</td>
<td>250</td>
<td>404</td>
</tr>
<tr>
<td>Pinot noir</td>
<td>2.43</td>
<td>26.5</td>
<td>2190</td>
<td>3.83</td>
<td>0.49</td>
<td>279</td>
<td>321</td>
<td>842</td>
<td>568</td>
</tr>
<tr>
<td>U0501-12</td>
<td>4.20</td>
<td>29.4</td>
<td>2900</td>
<td>3.87</td>
<td>0.68</td>
<td>420</td>
<td>88</td>
<td>802</td>
<td>979</td>
</tr>
<tr>
<td>U0502-01</td>
<td>2.90</td>
<td>25.9</td>
<td>2530</td>
<td>3.77</td>
<td>0.61</td>
<td>301</td>
<td>91</td>
<td>564</td>
<td>380</td>
</tr>
<tr>
<td>U0502-10</td>
<td>4.92</td>
<td>23.7</td>
<td>2220</td>
<td>3.48</td>
<td>0.85</td>
<td>301</td>
<td>87</td>
<td>588</td>
<td>845</td>
</tr>
<tr>
<td>Lenoir</td>
<td>4.32</td>
<td>26.9</td>
<td>2920</td>
<td>3.67</td>
<td>0.75</td>
<td>164</td>
<td>195</td>
<td>341</td>
<td>1801</td>
</tr>
<tr>
<td>Midsouth</td>
<td>4.60</td>
<td>18.2</td>
<td>2220</td>
<td>3.49</td>
<td>0.81</td>
<td>278</td>
<td>32</td>
<td>230</td>
<td>971</td>
</tr>
</tbody>
</table>

**Table 2c.** Sensory evaluation of reference varieties and advanced selections with the *PdR1* resistance source.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Juice Hue</th>
<th>Juice Intensity</th>
<th>Juice Flavor</th>
<th>Skin Flavor</th>
<th>Skin Tannin (1=low, 4= high)</th>
<th>Seed Color (1=gr, 4= br)</th>
<th>Seed Flavor</th>
<th>Seed Tannin (1=high, 4= low)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cab. Sauv.</td>
<td>pink-brown</td>
<td>light-med</td>
<td>fruity-CS</td>
<td>fruit jam</td>
<td>2</td>
<td>3</td>
<td>nutty-full</td>
<td>4</td>
</tr>
<tr>
<td>Pinot noir</td>
<td>pink-brown</td>
<td>medium</td>
<td>hay, honey</td>
<td>mildly fruity</td>
<td>1</td>
<td>4</td>
<td>spicy</td>
<td>4</td>
</tr>
<tr>
<td>U0501-12</td>
<td>red</td>
<td>med-dark</td>
<td>fruity</td>
<td>fruit jam</td>
<td>2</td>
<td>4</td>
<td>neutral</td>
<td>2</td>
</tr>
<tr>
<td>U0502-01</td>
<td>pink-brown</td>
<td>medium</td>
<td>fruity-PN</td>
<td>sweet fruit</td>
<td>1</td>
<td>3</td>
<td>spicy</td>
<td>1</td>
</tr>
<tr>
<td>U0502-10</td>
<td>pk-red-ong</td>
<td>med-dark</td>
<td>slight vegetal</td>
<td>mildly fruity</td>
<td>1</td>
<td>4</td>
<td>nutty,spicy</td>
<td>1</td>
</tr>
<tr>
<td>Lenoir</td>
<td>red</td>
<td>dark</td>
<td>mildly fruity</td>
<td>fruity</td>
<td>1</td>
<td>4</td>
<td>nutty</td>
<td>1</td>
</tr>
<tr>
<td>Midsouth</td>
<td>red-orange</td>
<td>med-dark</td>
<td>veg-fruity</td>
<td>neutral</td>
<td>1</td>
<td>4</td>
<td>neutral</td>
<td>4</td>
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