Long Term Evaluation of the Effects of Almond Leaf Scorch Disease on Orchard Productivity

Project No.: **08-PATH9-Sisterson**

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Objectives:

1. Compare yields of healthy and Almond Leaf Scorch infected trees.

2. Re-survey orchards to determine extent of *X. fastidiosa* spread since initial surveys in 2003/2004 and assess the fate of trees identified as infected in the initial survey.

Interpretive Summary:

Almond Leaf Scorch (ALS) disease has been present in California for more than 60 years. This disease is caused by the bacterium *Xylella fastidiosa* (Xf), which causes several other important plant diseases, most notably Pierce's disease of grapes. The disease is present in orchards throughout the state, but typically affects only a small proportion of trees, although in rare cases orchards have been severely affected. With the exception of planting resistant cultivars, there are no effective management strategies that prevent trees from becoming infected. Consequently, growers must often decide to keep or remove infected trees. The decision to keep or remove infected trees is a function of two components: risk of infected trees serving as sources for in-field, secondary pathogen spread and yield losses due to infection.

To assess the risk of infected trees serving as a source of inoculum, two orchards were surveyed repeatedly between 2003/2004 and 2008. Randomization tests were used to compare the mean percentage of trees infected surrounding newly infected trees for the observed data set and a simulated data set that distributed new infections randomly throughout the orchard. Results from one orchard found no increased risk of trees

becoming infected if they were adjacent to an infected tree identified in the first year of the survey. Results from the second orchard suggested a slightly higher risk of a tree becoming infected if it was adjacent to an infected tree. Combined, the results suggest that tree-to-tree spread is rare, but may occur.

Provided that infected trees do not serve as an important source of inoculum, the decision to keep or remove infected trees should be based off potential long term yield loss. To assess this, we compared the yields of ALS-affected and healthy trees for the past 5 years. We have consistently found that ALS-affected trees produced approximately 40% and 20% fewer kg of kernel than unaffected trees for the cultivars Sonora and Nonpareil, respectively.

The final factor to consider is the probability of tree death. Some reports suggest that ALS-affected trees should die within 3-8 years of symptom onset. To assess this risk we determined the fate of trees first identified as infected in 2003 or 2004. Tree death was observed at only one site, with 6% (6 out 105) of trees identified as infected in 2004 dying by 2008. However, at this site, 4% (10 out of 283) of trees identified as unaffected in 2004 also died or where nearly dead in 2008. Thus, it is likely that factors other than ALS contributed to tree death. The results suggest that death of ALS-affected trees over a 5-6 year period was rare.

Materials and Methods:

1. <u>Compare yields of healthy and infected trees</u>.
   Tree yields were evaluated at two sites: one in Fresno County and one in Kern County. Two almond cultivars were evaluated: Sonora and Nonpareil. The cultivar Sonora was evaluated at both sites. The cultivar Nonpareil was evaluated at only the Kern County site. For each cultivar by site combination, ten healthy and ten infected trees were evaluated. For each tree, kernel pounds per tree were estimated. Trees were shaken by growers according to their harvest schedule. Prior to nut collection by growers, we weighed all nuts and organic matter by hand collection. A four pound sub-sample was returned to the laboratory where the percentage of the sample which was organic matter and percentage weight of kernel to nut was estimated. These correction factors were used to estimate kernel pounds per tree.

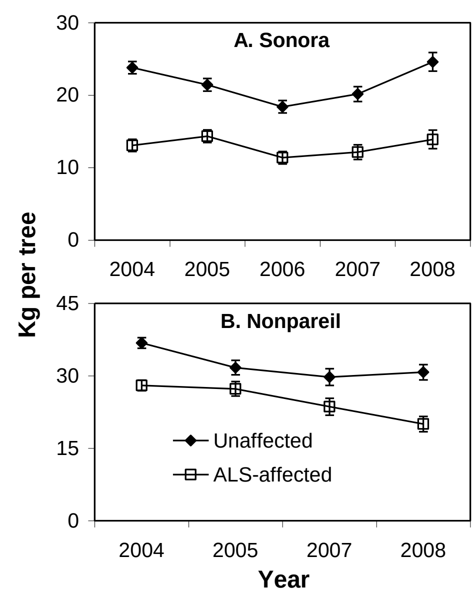

Fig. 1. Yields of ALS-affected and unaffected trees. A) Results for the cultivar Sonora averaged over 3 orchards (2004 to 2007) or 2 orchards (2008). B) Results for the cultivar Nonpareil from one orchard.

2. <u>Re-survey orchards to determine extent of *X. fastidiosa* spread since initial surveys in 2003/2004 and assess the fate of trees identified as infected in the initial survey.</u>
   In the fall of 2008, we resurveyed one orchard in Kern County and one Orchard in Fresno County. The orchard in Kern County was first surveyed in

2003, thus our assessment in the fall of 2008 provided data on the degree of *X. fastidiosa* spread over a 6 year period. Similarly, the orchard in Fresno County was first surveyed in 2004, thus this reassessment provided data on the extent of *X. fastidiosa* spread over a 5 year period. During each survey all trees were rated on a scale of 1 (healthy) to 4 (all scaffolds showing symptoms). Samples were collected from trees showing symptoms to confirm the presence of *X. fastidiosa* using PCR based methods. Similarly, the fate of all trees identified as infected in the initial survey was assessed to determine the extent of tree mortality or removal. The distribution of infected trees in the initial survey was compared to the current survey to assess the probability that tree-to-tree spread occurred.

Results and Discussion:

1. <u>Compare yields of healthy and infected trees.</u>
   Results for 2008 are consistent with previous findings. Specifically, ALS-affected trees produced approximately 40% and 20% fewer kg of kernel than unaffected trees for the cultivars Sonora and Nonpareil, respectively (**Figure 1**).
2. <u>Re-survey orchards to determine extent of *X. fastidiosa* spread since initial surveys in 2003/2004 and assess the fate of trees identified as infected in the initial survey.</u>
   The Fresno County orchard consisted of alternating rows of Neplus and Sonora. In 2004, 1 Neplus and 105 Sonora trees were infected with *X. fastidiosa*. Between 2004 and 2008, an additional 1 Neplus and 17 Sonora trees were determined to be infected with *X. fastidiosa*. This represents an increase of 0.25 and 4 infected Neplus and Sonora trees per year, respectively. Randomization test were used to assess whether infected trees detected in 2004 served as a source of inoculum for infections detected in subsequent years. The analysis compared the mean percentage of trees infected surrounding newly infected trees for the observed data set and a simulated data set that distributed new infections randomly throughout the orchard. The analysis was completed for a distance of 1 to 10 trees from newly infected trees. The analysis suggested that the distribution of newly infected trees at the Fresno County orchard was random in relation to the location of previously infected trees, suggesting that there was no tree-to-tree spread (**Figure 2**).

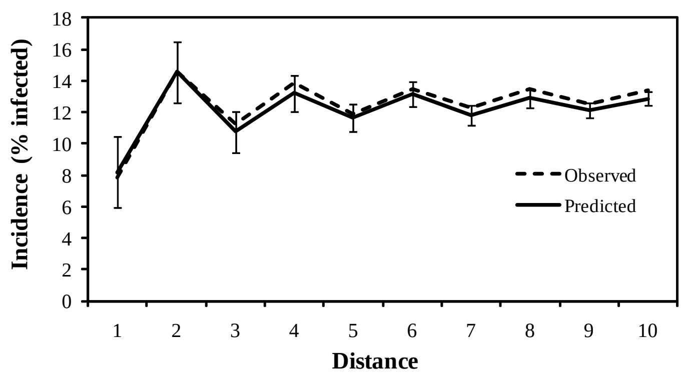

Fig. 2. Observed proximity of trees infected after 2004 to previously infected trees versus the proximity predicted if infections were distributed randomly for the Fresno County orchard.

The Kern County orchard consisted of the cultivars Fritz, Nonpareil, and Sonora. In 2003, 1 Fritz, 23 Nonpareil, and 53 Sonora trees were infected with *X. fastidiosa*. Between 2003 and 2008, an additional 1 Fritz, 18 Nonpareil, and 20 Sonora trees were determined to be infected. This represents an increase of 0.21, 3, and 4 infected Fritz, Nonpareil, and Sonora trees per year, respectively. The randomization test suggested that trees infected after 2003 were in greater proximity to previously infected trees than would be expected if infections were randomly distributed throughout the orchard for a distance of 1 tree (**Figure 3**). A second analysis assessing the probability of tree-to-tree spread after 2004 found no difference between the observed distribution and those of the random distribution model. Combined, the results of the randomization test suggest that some tree-to-tree spread may have occurred between 2003 and 2004, but that no tree-to-tree spread occurred between 2004 and 2008.

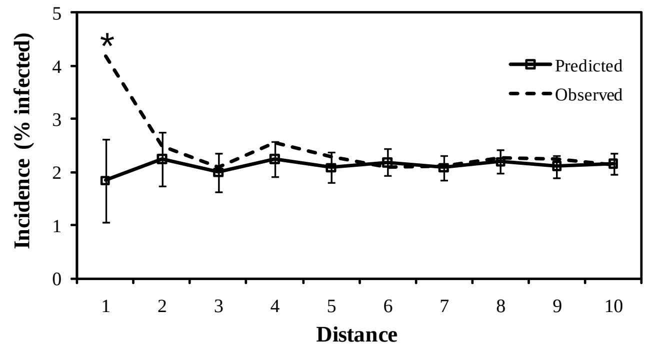

Fig. 3. Observed proximity of trees infected after 2003 to previously infected trees versus the proximity predicted if infections were distributed randomly for the Kern County orchard.

The final factor evaluated was the probability of tree death. To assess this risk we determined the fate of trees first identified as infected in 2003 or 2004 (**Table 1**). Tree death was observed at only one site, with 6% (6 out 105) of trees identified as infected in 2004 dying by 2008. However, at this site, 4% (10 out of 283) of trees identified as unaffected in 2004 also died or where nearly dead in 2008. Thus, it is likely that factors other than ALS contributed to tree death. Together, the results suggest that death of ALS-affected trees over a 5-6 year period was rare.

Table 1. Results of orchard survey. Orchards were surveyed in 2003 or 2004. Then in 2008, the status of trees identified as being infected in the first survey was re-assessed.

			1st Survey			Status of infected trees in 2008			
Orchard	Cultivar	Total num. of trees	Num. Infected	Mean rating[a]	Year of survey	Num. alive	Num. dead	Num. Removed	Mean rating[a]
A	Sonora	388	105	3.6	2004	90	6	9	3.6
B	Sonora	896	53	3.4	2003	13	0	40	3.0
B	Nonpareil	1,728	23	2.6	2003	23	0	0	3.7

[a] Trees were rated on a scale of 1 (healthy) to 4 (all scaffolds symptomatic for ALS).

Recent Publications:

Sisterson, M. S., J. Chen, M. A. Viveros, E. L. Civerolo, C. Ledbetter, & R. L. Groves. 2008. Effects of almond leaf scorch disease on almond yield: implications for management. Plant Disease 92: 409-414.