Development and Optimization of the Steam Auger for Management of Almond Replant Disease

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Objectives:

The overall goal of this project is to develop and optimize steam spot treatments for control of almond replant disease without the use of soil fumigants. The specific objectives include:

- Optimize spot steam treatment equipment and techniques for replanting orchards with varying soil texture, moisture, and temperature and soil borne pest pressure.
- Monitor effects of spot steam treatments on early growth of stonefruit and almond trees, compared to conventional fumigant-based treatments for preventing replant disease.
- Evaluate the economic viability and technical feasibility of spot steam treatments using large, commercially relevant field plots.

Figure 1. Redesigned steam-injection auger for treating almond tree planting sites. A 24-inch diameter auger (in use) and a 36 inch auger (foreground) were tested in trials throughout the San Joaquin Valley, CA.

Background:

Replant disease (RD) can be a significant problem in second and later generation orchards and is caused by a host-specific soilborne microbial complex associated with cultivation of *Prunus* species. RD results in moderate to severe suppression of early root and shoot development, although trees typically overcome disease, it can rob early and cumulative productive potential.

Pre-plant soil fumigation reduces replant problems, but increasing regulatory restrictions are complicating use of these treatments. With the phase out of methyl bromide (MB) in 2005, use has shifted to other fumigants including 1,3-dichloropropene (1,3-D) and chloropicrin (CP). These fumigant alternatives have use restrictions due to environmental and human safety concerns, so non-fumigant alternatives are needed for areas where grower preference or regulations limit fumigant use.

Materials and Methods:

- Preliminary tests of an auger-based steam injection technique were initiated in December 2009. The Madera trial was terminated after severe glyphosate herbicide injury stunted and killed many trees resulting in substantial replants. A trial near Atwater is ongoing.
- Two new augers, 24 and 36 inches, designed and built during 2010 are similar to each other and include carbide tipped cutting teeth for easier digging and steeper and truncated flighting to increase soil mixing and minimize soil ejection (**Figure 1**). Additional holes were also cut in the flighting of the 36 inch auger to allow more vertical mixing of soil.
- Several small plot experiments (two tree plots) were conducted throughout the San Joaquin Valley to directly compare the effects of three levels of soil disturbance to steam auger thermal treatments. Trials were initiated near Delhi December 2010, near Atwater January 2012, and in Livingston in February 2012. (**Table 1**).
- Large plot experiments (24-tree plots) were treated with several soil fumigation treatments or the 36 inch steam auger (**Figure 1 and 2**). Trials were initiated near Delhi in December 2010 and Atwater in December 2012.

Figure 2. Disease severity ratings for large plot steam and fumigant treatments in an almond orchard replant trial initiated in 2010 near Delhi, CA. P=.05

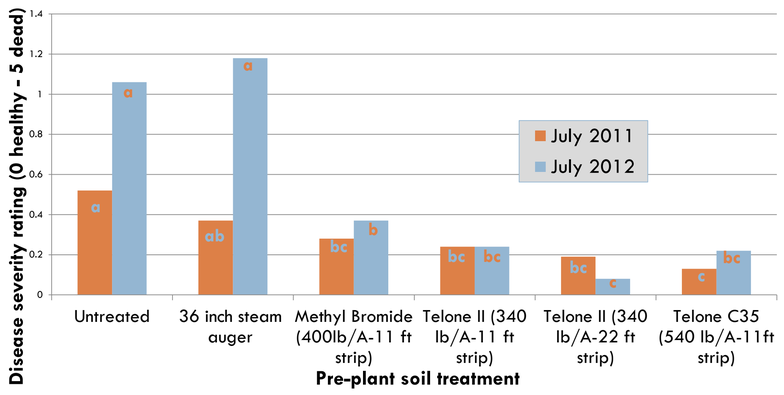


Figure 3. Change in diameter for large plot steam and fumigant treatments in an almond orchard replant trial initiated in 2010 near Delhi, CA. P=.05

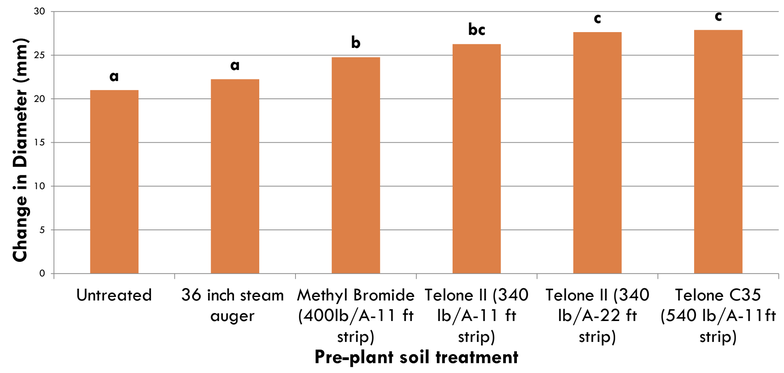
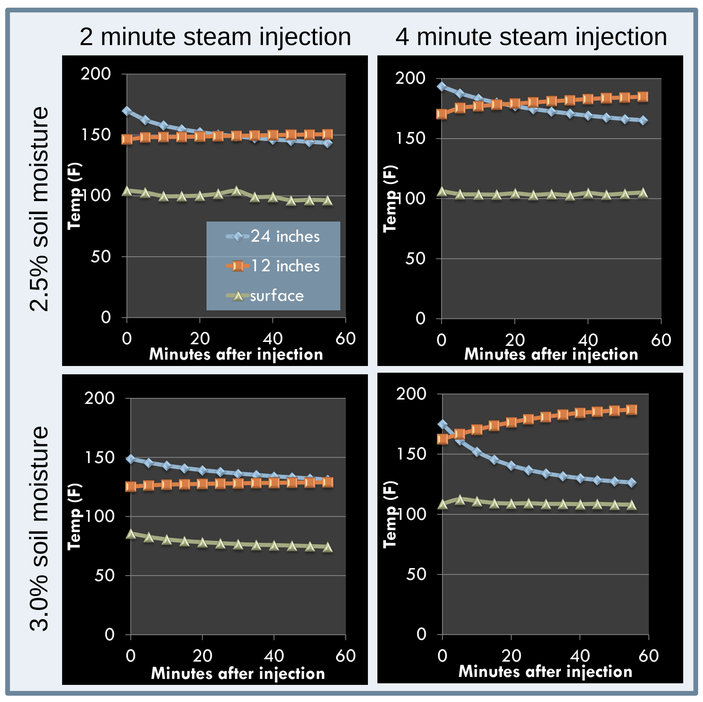


Figure 4. Selected temperature profiles from mechanistic trials with 36" auger to determine optimum steam injection time and soil moisture.



- Near Wasco a separate trial was initiated in May 2011. At this site, 24 and 36 inch auger treatments with and without steam injection were compared in four-tree plots replicated eight times. Treatments in this experiment also included a high rate of shank-injected chloropicrin, several non-fumigant fungicides and soil amendments.
- Steam injection regimens of 4 to 4.5 minutes per tree site and 2 to 2.5 minutes per tree site were used to achieve the target temperature of 158F with the 36 inch auger and the 24 inch auger respectively (**Figure 4.)**
- For all trials baseline trunk caliper data were collected during the dormant season shortly after planting and annually thereafter. Disease severity ratings are made annually during the growing season and assigned on a scale of 0 to 5 where 0 = very healthy plant and 5 = death.

Table 1. Steam auger treatments in an almond orchard replant trials throughout the San Joaquin Valley. P=.05

	Delhi[1]		Atwater	Livingston
Pre-plant Treatment	Disease[2] rating 7/25/12	Trunk Growth 2011-2012 (mm)	Disease rating 7/24/12	Disease rating 7/24/12
none	1.5	16.2 b	1	1
24 inch auger	1.1	18.8 ab	1.2	1.3
36 inch auger	1.1	19.4 ab	0.9	1.4
Backhoe: 4 x 4 x 2 ft	1	20.5 a	0.6	0.8
24 inch auger + steam	1	20.8 a	1	0.8
36 inch auger + steam	1.2	21.3 a	0.5	1.1

1. The Delhi site was initiated in December 2010, the Atwater site was initiated in January 2012 and the Livingston site was initiated in February 2012.
2. Disease rating scale is (0=healthy to 5=dead).

Results and Discussion:

- The two preliminary trials initiated in 2009 informed the redesign and refinement of the steam injection augers. The ongoing Atwater trial will also give the longest evaluation period and early yield assessment.
- Tree growth data from the small plot trial near Delhi shows minor differences between the control and the best treatment, but no difference among other treatments (**Table 1**). First year disease ratings from the small plot trials in Atwater and Livingston showed no differences (**Table 1**).
- In the large plot trial near Delhi, the differences in disease severity increased in the second year and was significantly greater in untreated and steam treated plots than in all fumigated plots (**Figure 2**). Additionally all plots receiving a fumigant treatment showed significantly greater increase in trunk diameter than did the plots not receiving fumigation (**Figure 3**).
- First year disease severity ratings of the large plot trial near Atwater seem to be in agreement with results from the Delhi trial in that all fumigated plots performed better than untreated and steam treated plots (data not shown).
- At the Wasco site fumigation appeared to provide better control of replant disease than disturbance and steam treatments (**Table 2**).

Table 2. Selected fumigant and non-fumigant treatments in an orchard replant trial near Wasco, CA[1]

Pre-plant Treatment	Change in Diameter (2011-2012)	Disease Rating (0=healthy to 5=dead)			
		6/15/11	7/12/11	8/12/11	7/25/12
Chloropicrin[2]	9.30	0.07	0.86	0.38	0.49
Untreated	7.62	0.00	1.06	0.44	1.06
24 inch auger	6.29	0.03	1.22	0.91	1.34
36 inch auger	6.72	0.00	1.00	0.58	1.55
24 inch auger + steam	6.98	0.03	0.84	0.75	1.16
36 inch auger + steam	8.02	0.03	0.94	0.63	1.06

1. Wasco trial was initiated in May 2011 and was planted with potted trees in June.
2. Chloropicrin was applied at rate of 300lb/ac to a 8.33 ft strip in the tree row.

Acknowledgements

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