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

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Objectives:

Our approach in the current research is to combine the benefits of limited area fumigation treatments (spot treatments) with thermal soil disinfestation using steam applied with an auger-based injection unit. 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:

1. **Monitor early vigor of the almond orchards planted following winter 2009 steam treatments.**
2. **Optimize the design and application techniques for steam treatments of future tree sites.**
3. **Scale-up of the steam auger soil treatments to larger areas to assess technical feasibility and economic viability.**

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 root and shoot development and is most evident in the first year after planting (**Figure 1**). Although trees typically overcome disease, it can rob early and cumulative productive potential. It is estimated that well over half of California's almond acreage is at risk for RD.

***Figure 1**: Stonefruit replant trial near Parlier, CA. Trees in the foreground were planted in fumigated soil while trees in the background were planted in unfumigated soil.*

Pre-plant soil fumigation, especially with methyl bromide (MB), has been used to prevent several replant problems. However, with the phase out of MB in 2005, use has shifted to other fumigants including 1,3-dichloropropene (1,3-D) and chloropicrin (CP). CP and mixtures of CP with other fumigants can provide excellent control of RD. Spot fumigation treatments, treating only about 10% of the orchard floor, with CP or CP + 1,3-D, were recently shown to provide adequate RD control. Use of soil fumigation treatments, however, is increasingly subject to regulatory complications including: the phase out of MB, Telone Township use caps, emissions of volatile organic compounds, and the reregistration of soil fumigants.

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***Figure 2. Steam auger in operation at a site near Delhi**.*

2009

Two trials were established near Atwater and Madera to compare steam treatments to various shank-applied fumigants. Steam was applied for four minutes per tree site to reach or exceed the temperature threshold of 156ºF (**Figure 2**). It is not known if this treatment is uniformly applicable to other soil types or soil moisture conditions. These two sites were planted with bareroot trees in winter 2010. Height and trunk diameter will be recorded yearly as well as monthly overall health ratings. The Madera trial was compromised in 2010 by glyphosate herbicide injury and was terminated. The Atwater site also had minor inconsistencies in growth due to irrigation and other horticultural practices; however, second season growth and disease ratings suggest that treatment effects may become apparent (**Table 1**).

Table 1. Selected fumigant and non-fumigant treatments in an almond replant trial initiated in winter 2009 near Atwater, CA

Fumigant treatment[1]	Tree site treatment[2]	Disease rating July 12, 2010 (0-5 scale)	Disease rating July 19, 2011 (0-5 scale)
None	None	0.42	0.81
None	Auger-only	0.17	0.42
None	Auger + steam	0.23	0.73
None	Auger + BSM	0.21	0.54
None	Auger + BSM + steam	0.09	0.80
Telone C35 (8 ft strip)	None	0.04	0.08
Telone C35 (8 ft strip)	Auger-only	0.17	0
Telone C35 (8 ft strip)	Auger + steam	0	0.08
Telone C35 (8 ft strip)	Auger + BSM	0	0
Telone C35 (8 ft strip)	Auger + BSM + steam	0	0
P-value for tree site treatment (within fumigant)		NS	NS

[1] Telone C35 (540 lb/A) was applied with a commercial application rig in an 8.3 ft strip.
[2] Steam was applied through a 30-inch diameter auger for sufficient time to raise the soil temperature above 156 F for at least 30 minutes. Brassica seed meal (BSM) was applied at approximate 4000 lb/A by pouring dry meal into the tree site while the auger was mixing the soil.

2010

Two new augers were designed and built during 2010 and tested in commercial orchards near Delhi and Wasco in winter and spring 2011. The augers were similar in design except that one has a 24 inch diameter and one is 36 inches across **(Figure 3).** Changes included: carbide tips and cutting teeth, steeper flight pitch, truncated flighting, and holes in the flighting of the 36-inch auger to increase the vertical mixing of soil.

***Figure 3:** 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 near Delhi and Wasco, CA.*

At Delhi, the steam auger was tested in two separate experiments. A small plot experiment was conducted to directly compare the effects of three levels of soil disturbance to steam auger thermal treatments (**Table 2**).

In a separate large plot experiment at the same site, 24-tree plots were treated with several soil fumigation treatments or the 36-inch steam auger (**Table 3**). A steam injection regiment of 2 to 2.5 minutes per tree site with the 36-inch auger was used to achieve the target temperature in this cool, moist, sandy soil. The Delhi site was planted with bareroot trees in January 2011. Initial disease severity ratings suggest that a minor case of the replant disease exists but at this early stage there were few statistical differences among treatments (**Tables 2 and 3**).

Table 2. Steam auger treatments in an almond orchard replant trial initiated in winter 2010 near Delhi, CA

Application equipment	Treatment[1]	Disease rating July 19, 2011 (0-5 scale)
none	none	0.81
24 inch auger	disturbance only	0.53
36 inch auger	disturbance only	0.76
backhoe	4x4x2 ft disturbance only	0.92
24 inch auger	steam injection	0.63
36 inch auger	steam injection	0.50

[1] Steam was applied for enough time to raise the soil temperature above 156 F for at least 30 minutes (2-4 minutes of steam injection).

2011

At the Wasco site, 24- and 36-inch auger treatments with and without steam injection were compared with other treatments including a high rate of shank-injected chloropicrin and several non-fumigant fungicides or soil amendments. This site was planted in June 2011 with potted, non-dormant almond nursery stock. Initial base line trunk caliper data were collected and first year disease severity ratings were made in summer 2011, but have not yet been analyzed.

Several new sites will be identified for initiation during the winter of 2011-12. Steam application time will be varied from less than one minute to over five minutes per tree site and soil temperatures will be monitored for a 24 hour period before and after steam application at depths of 2, 12 and 24 inches. Data will be analyzed and the most efficient yet effective treatment schedule will be determined. If the treatment duration can be shortened without reducing efficacy, the economic viability of steam auger treatments can be greatly improved.

Table 3. Large plot steam auger and soil fumigation treatments in an almond orchard replant trial initiated in winter 2010 near Delhi, CA

Treatement[1]	Treated area	Disease rating July 19, 2011 (0-5 scale)
Untreated	None	0.49 a
methyl bromide	400 lb/A – 11 ft strip	0.27 bc
Telone II	340 lb/A – 11 ft strip	0.20 c
Telone II	340 lb/A – 22 ft strip	0.15 c
Telone C35	540 lb/A – 11 ft strip	0.15 c
36 inch steam auger	steam injection	0.40 ab

[1] Fumigants were applied by TriCal, Inc. Steam was applied for enough time to raise the soil temperature above 156 F for at least 30 minutes (2-4 minutes of steam injection).

Conclusion

Although this research is at an early stage, we anticipate being able to draw meaningful conclusions on the viability of steam disinfestation for almond replant disease management within the next two growing seasons. Our early data suggests that steam disinfestation is not likely to provide the same level of replant disease management as chemical fumigants. However, tree site steaming or other non-fumigant approaches being tested may be useful to almond growers unable or unwilling to use soil fumigants.