
Spot-Steamming of Planting Sites as a Methyl Bromide Alternative to Manage the 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 (RD). The specific objectives include:

1. Design and optimize application systems for steam treatments to control almond RD.
2. For pre-plant spot steam treatments applied to tree planting sites, determine the depth of soil that must be treated and the temperatures that must be achieved for control of almond RD.
3. Assess the economic viability of proposed steam application techniques.

Interpretive Summary:

We built and tested a system to steam pasteurize almond tree planting sites with the goal of controlling replant disease. The steam injection is based on an auger design by researchers in Canada (Moyle and Hocking, 1994) who used steam to control replant disease in apples. The method involves injecting steam into a tree site using a steam generator and an auger equipped with a rotating steam union. The rotating steam union allows steam to be delivered from a stationary steam generator into a rotating shaft. The prototype auger is driven by a hydraulic motor attached to a tractor 3-point hitch and hydraulics to drive the system (**Figure 1**). The drive gearbox is designed to permit use of a hollow shaft so that the steam injected into the rotating steam union will pass through the gearbox and into the hollow auger shaft. At the bottom of the auger flighting, steam is injected into the soil through a set of orifices. Two auger diameters were tested, 24-in and 36-in, and both are designed to inject steam to depths of 24-in deep. Two replicated field tests of the system were conducted during December 2009

near Atwater and Madera, CA. Generally the soil heating time was excellent at 12 to 24 inches deep. However, work must be done to ensure that the upper 6-in of the tree site are heated adequately to kill soil pathogens. We propose to use an insulator to more completely trap heat at the top of the tree site.

Estimated costs were determined to be \$509 per acre based on 90 trees per acre. We believe that these costs can be reduced by operating two augers per steam generator which will likely reduce treatment times and cost per acre.

Materials and Methods:

Objective 1. Design and optimize application systems for steam treatments to control almond RD.

Steam disperses slowly in soil unless the soil is physically mixed (Baker 1957). Therefore, we chose the auger design of Moyls and Hocking (1994). This design uses an auger to inject steam into the soil while the auger is turning. Two augers were constructed, a 36-in. diameter unit by UC and USDA personnel (**Figure 1**) and a 24-in diameter unit by a cooperator (**Figure 2**). To kill soil pathogens the temperature in the tree site must meet or exceed 158°F for 20 minutes throughout the treated zone.

Objective 2. For pre-plant spot steam treatments applied to tree planting sites, determine the depth of soil that must be treated and the temperatures that must be achieved for control of almond RD.

Two trials were established near Atwater on Dec. 2 to 4 and Madera on Dec. 16 to 17, 2009 in an experimental design that allows comparison of steam treatments to various shank-applied fumigants. Soil temperatures were measured with analog compost thermometers, and Hobo electronic temperature monitors set at 6, 12, 18 and 24-in deep in the tree site. Bare-root almond nursery stocks were planted by the cooperating growers in Jan. 2010. Research personnel will collect tree height and trunk diameter after planting and annually thereafter for several growing seasons. Monthly overall health ratings on a scale of 0 to 5 where 0 = very healthy plant and 5 = death will be taken during the growing season. Before and after treatments, soil samples will be collected and characterized for microbial population, nematode population, soil pH, electrical conductivity and nutrient levels. Data will be subjected to analysis of variance.

Objective 3. Assess the economic viability of proposed steam application techniques.

Measurements were taken of the time to heat soil in the tree sites to 158°F for 20 minutes to a depth of 24-in. Fuel consumption and soil temperatures were monitored to estimate the cost and viability of the treatment. At the Atwater site the treatment time was 4 minutes per tree site and at Madera 5 minutes per tree site. The rate of fuel consumption on the propane fueled steam generator was 12 gallons per hour or 0.2 gallons per minute.

Results and Discussion:

Objectives 1 & 2. Two functional steam injection augers were completed and operated in December 2009 at two sites being prepared for almond planting (**Figures 1 and 2**). The Temperature profile was satisfactory at the 12, 18 and 24-in deep levels (**Figure 3**). However, at the 6-in level the soil rapidly cooled. In future studies we will test the use of insulation to prevent the heat loss at the surface. Assessments of the tree vigor were not available at the reporting press time and will be reported at the Almond Expo and in future reports.

Objective 3. Based on a treatment time of 8 hours per acre and a density of 90 trees per acre, the cost was estimated at \$509 per acre or \$5.66 per tree site (**Table 1**). We were only able to field one auger at a time in this preliminary study, but our 25 horsepower propane steam generator has the capacity to simultaneously supply steam to two augers, i.e., increase operational efficiency. We assume that operating two augers per steam generator would reduce the treatment time per acre to 4 hours and reduce the machine and fuel cost for the steam generator. We propose to scale up to a commercial level treatment system that would reduce these costs by reducing treatment time per acre.

Research Effort Recent Publications:

- Fennimore, S., B. Hanson, G. Browne, and J. Samtani. 2009. Spot-steaming of planting sites as a methyl bromide alternative to manage almond replant disease. 2009 Proceedings. Almond Board of California. Modesto, CA. Pp. 262-263.
- Fennimore, S.A. and R.E. Goodhue. 2009. Estimated costs to disinfest soil with steam. *In*: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions. San Diego, CA. Proceedings 3.

References Cited:

- Baker, K.F. 1957. The U.C. system for producing healthy container-grown plants. Manual 23; Univ. Calif. Agric. Exp. Sta. Berkeley, CA.
- Moyls, A.L. and R.P. Hocking. 1994. In situ soil steaming for the control of apple replant disease. *Appl. Eng. Agric.* 10:59-63.

Table 1. Estimated costs per acre to steam tree sites with a steam injection auger using one auger alone with a propane fuel steam generator.¹

Expense	Cost \$ per acre	Cost \$ per tree site
Propane fuel	197	2.19
Machine cost for auger and steam generator	145	1.61
Labor cost for tractor driver and steam generator operator	167	1.86
Total	509	5.66

¹ Auger cost was \$12,715, Steam generator cost was \$81,150, propane fuel cost was \$2.19/gal., steam operator labor was \$17.55/hour, and field labor was \$13.50/hour



Figure 1. . Finished auger fabrication on Nov. 7, 2009. Shown are the auger, gear box, 3-pt. connection and hydraulic drive.



Figure 2. Tree site steam auger treatments in a field trial near Atwater, CA in December 2009. Almond growth and vigor in plots treated with steam disinfection treatments will be compared to plots treated with soil fumigants.

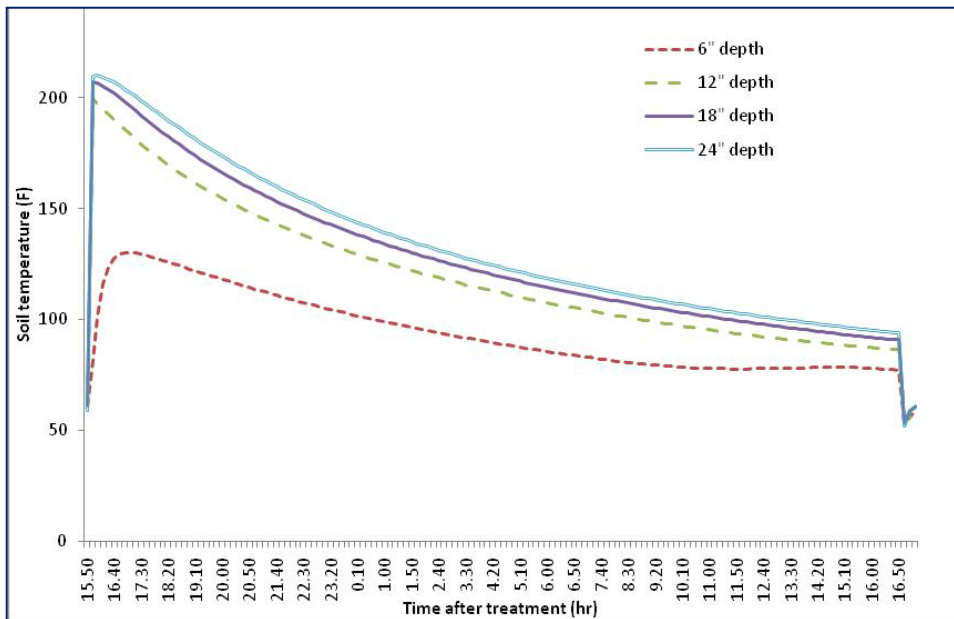


Figure 3. Soil temperature response for 24 hrs following tree site treatment with the steam auger. Initial and final points in each curve represent air temperature (~60° F) during the trial. At depths of 12 inches or greater, temperature was maintained above 158° F for more than 3.5 hours after steam injection. Initial and final points in each curve represent air temperature (~60° F).