# OPTIMIZING ANAEROBIC SOIL DISINFESTATION FOR STRAWBERRY PRODUCTION IN CALIFORNIA

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Considerable financial resources are being invested in the search for chemical fumigant alternatives to methyl bromide (MeBr). However, current re-registration and regulation processes may severely limit the sustainability of fumigant-dependent production systems. Soilborne disease management without use of chemical fumigants is one of the greatest challenges for strawberry production in California. Developed in Japan (Momma, 2008) and the Netherlands (Messiha et al., 2007), anaerobic soil disinfestation (ASD), a non-chemical alternative to MeBr, can control soilborne pathogens and nematodes in strawberries and vegetables. In Japan, hundreds of farmers use ASD to control soilborne pathogens (including *Verticillium dahliae*) and nematodes in strawberries and vegetables grown in greenhouses.

ASD integrates principles behind solarization and flooding to control nematodes and pathogens in situations where neither is effective or feasible. ASD works by creating anaerobic soil conditions by incorporating readily available carbon-sources into topsoil that is irrigated to saturation (**not flooded**) and subsequently covered with a plastic tarp. The tarp is then left in place to maintain soil moisture above field capacity. Anaerobic decomposers are then able to respire using the added carbon, which results in the build-up of anaerobic by-products that are toxic to pathogens (Katase et al., 2009), but that are degraded rapidly once the tarp is removed or holes are made through the tarp for planting.

To optimize ASD for California strawberries, we have conducted a series of pot and field experiments over the last three years. In the 2009-2010 season, a pot experiment showed that wheat bran, rice bran, mustard cake, grape pomace, and ethanol all reduced *V. dahliae* propagules when used as a C source for ASD (Fig. 1). Of these, rice bran from the Northern California rice industry seems to be the best choice in terms of costs ($150 per ton plus shipping as of July 2010), availability (> 75,000 tons are available in CA annually), and ease of handling. While mustard cake performed extremely well in pot studies, it is not feasible to use at a rate of 4.5ton $ac^{-1}$ in the field due to high cost (> $1/lb) and the large amount of N that would be added (~6% N).

After earlier problems achieving strong reducing conditions (due to issues of inadequate irrigation or incorporation of the C source), we have successfully obtained Eh reductions near or exceeding 50,000 mVhr using ASD in the field at

Ventura (2009) (Fig. 2) and Watsonville (2009-10) (Fig. 3). This level was identified as a threshold for effective reductions in *V. dahliae* propagules at 25 °C based on earlier pot experiments (Shennan et al., 2009). ASD reduced native *V. dahliae* populations by 16-80% depending on tarp type and irrigation in a very heavily-infested field in Ventura (2009) and by an average of 88% in Salinas (2008-9). Notably, in the Salinas trial, native *V. dahliae* populations in soils of ASD plots were equal to, or lower than the In-Line (chloropicrin + 1,3-dichloropropene) fumigant-treated surrounding area (Fig. 4). Strawberry fruit yield in ASD plots in a site with very low *V. dahliae* pressure was comparable with both the untreated check and the surrounding MeBr-treated fields, showing there is no carryover of toxicity of ASD to strawberry plants. Currently, two replicated on-farm trials comparing three different ASD options, untreated checks, and MeBr controls are in progress in Watsonville and Salinas.

Overall, we found that ASD can be very effective at the field scale in strawberry systems in coastal CA with sandy loam to silty clay loam soils using 4.5 to 9 tons $ac^{-1}$ of rice bran and 3 to 5 ac-in of intermittently applied drip-irrigated water in bed treatment. However, we also found that the level of control is not consistent across all studies and treatments. Prior pot studies suggested that at lower temperatures (15°C), there was not a clear relationship between pathogen suppression and Cumulative Eh as was observed at 25°C. With the exception of the Ventura trial, our field trials experienced low soil temperatures of ~15 ºC and below during ASD treatments (Shennan et al., 2009). Nonetheless, Dutch studies and our data from an earlier field study at the UCSC farm show that good disease suppression can be achieved with longer tarping periods at temperatures in the 15 to 25°C range. To address this question, we will do further pot experiments (varying both temperature and tarping time) and field tests with different dates and tarping times to better identify relationships between tarping time, soil temperatures, Eh, and disease and weed suppression.

**References**

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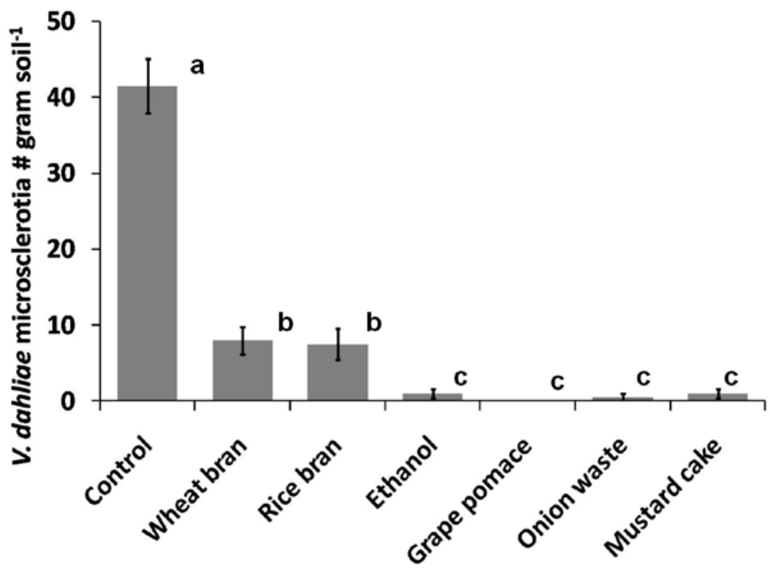


Figure 1. *Verticillium dahliae* population in retrieved inocula after three weeks of ASD treatment with varying carbon sources applied at a rate of 4.5 tons $ac^{-1}$ equivalent of dry solid material or at 4” equivalent of liquid (1% ethanol). Values are back-transformed means ± SEMs. No significant difference was observed between factors with the same letter by Tukey’s HSD test at the *P*=0.05. n=4 for each treatment (pot experiment).

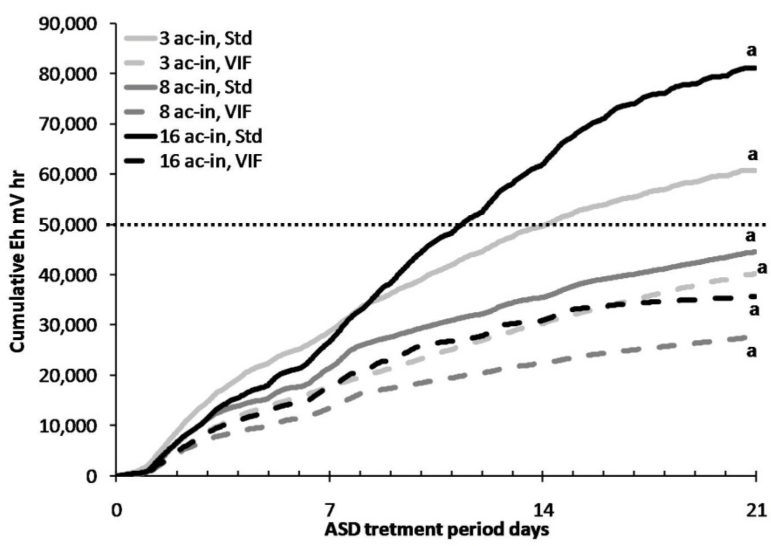


Figure 2. Cumulative Eh in the Ventura trial (Jun.-Jul. 2009). Values are averages of 5 replicates in mVhrs. Treatments are Std (standard black tarp, 1.5 mil) or VIF (virtually impermeable film, black.1.25 mil) with 3, 8 or 16 ac-in of irrigation. No significant difference was observed between treatments with the same letter on the 21st day by Tukey’s HSD test at the *P*=0.05.

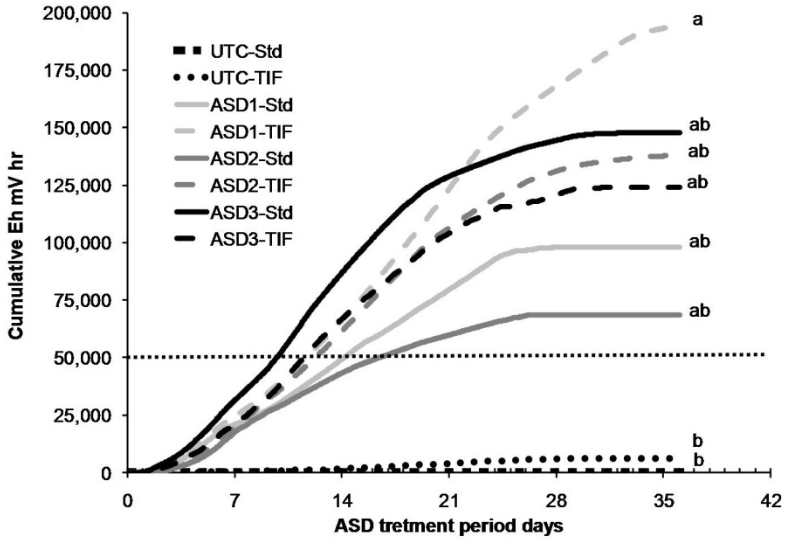


Figure 3. Cumulative Eh in the Watsonville trial (Oct.-Nov. 2009). UTC: untreated check. ASD 1: rice bran 4.5 tons ac$^{-1}$, ASD 2: rice bran 9 tons ac$^{-1}$, ASD 3: rice bran 8 tons ac$^{-1}$ + mustard cake 1 ton ac$^{-1}$, Std: standard plastic tarp (green, 1.25 mil), TIF: totally impermeable film (clear, 1.2 mil). Values are averages of 4 replicates. No significant difference was observed between treatments with the same letter on the 36th day by Tukey's HSD test at the *P*=0.05.

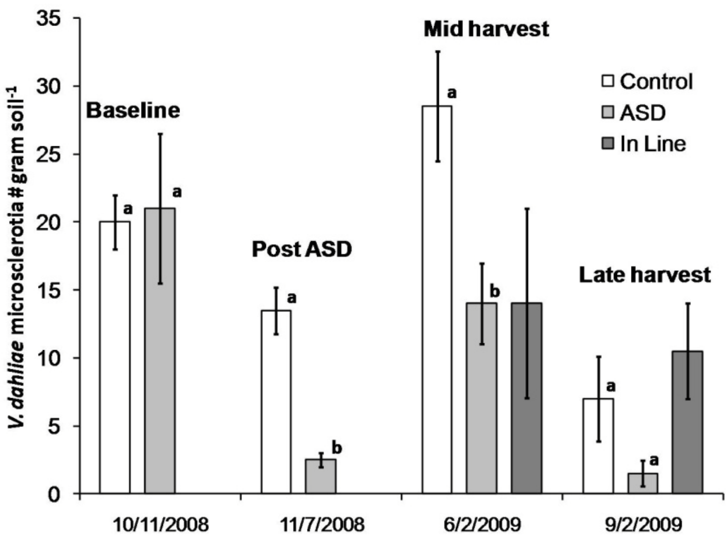


Figure 4. Effect of ASD on native *Verticillium dahliae* population in soils in the Salinas trial (2008-09). Control: no carbon sources and no irrigation. ASD: 4.5 tons ac$^{-1}$ of rice bran. Values are back-transformed means ± SEMs. No significant difference was observed between treatments with the same letter on the same date by Tukey's HSD test at the *P*=0.05. On 6/2/2009 and 9/2/2009, soils from surrounding In Line-treated field were also analyzed for *V. dahliae* population and data are shown for comparison.