# ANAEROBIC SOIL DISINFESTATION FOR CONTROLLING FUSARIUM WILT IN STRAWBERRIES

Joji Muramoto*, Carol Shennan, and Margherita Zavatta, University of California, Santa Cruz; Mark Mazzola, USDA-ARS, Wenatchee, WA; Kelly Ivors, California Polytechnic State University, San Luis Obispo

Anaerobic soil disinfestation (ASD) has been shown to be effective in controlling Verticillium wilt and to provide marketable fruit yields comparable to fumigation in California (CA) strawberry systems (Shennan et al., 2017). ASD also reduced charcoal rot mortality in strawberries caused by *Macrophomina phaseolina* by 50% two years in a row in an organic site in southern CA (Shennan et al., 2015). In the 2016-17 season, the ASD-treated acreage for strawberries and cane berries exceeded 1,400 acres in California.

Fusarium wilt, caused by *Fusarium oxysporum* f. sp. *fragariae* (Fof), is an emerging soilborne disease of strawberries in CA. Fusarium wilt can also be controlled by ASD, however on some occasions has provided inconsistent control. One study showed that higher soil temperatures were necessary to control Fusarium wilt by ASD (> 300 cumulative hours above 86 °F at 8” soil depth during the treatment (Yonemoto et al., 2006)). In the 2013-14 season, we demonstrated that ASD summer flat treatment using 9 t/ac of rice bran and clear TIF could exceed the temperature threshold, resulting in reduced Fof soil densities and plant mortality at Watsonville, CA (Muramoto et al., 2015). However, summer flat ASD may not be feasible for many berry growers who do not have access to the field until fall. Butler et al. (2014) suggested that amendment rates may need to be as high as 4 mg-C/g soil for effective soil disinfestation at moderate soil temperatures. Further, by using a cultivar resistant to Fusarium wilt, ASD may be able to increase fruit yield in an Fof infested field.

Here we report on the 2015-16 and the 2016-17 trials at the same site that aimed to 1) examine whether ASD fall bed treatment with higher C-source rates (12 to 15 t/ac (= 6-8 mg-C/g soil)) can control Fusarium wilt of strawberries (2015-16), and 2) test whether a combination of fall bed ASD along with a resistant cultivar can produce yields comparable to the fumigated control in an Fof infested field (2016-17).

The 2015-16 trial consisted of a randomized complete block design with 4 replicates, and included fall bed ASD with: grape pomace 12 t/ac (GP12) and 15 t/ac (GP15), grass hay 12 t/ac (GH12) and 15 t/ac (GH15), rice bran 9 t/ac + grape pomace 6 t/ac (RB9+GP6), wheat bran 9 t/ac + grape pomace 6 t/ac (WB9+GP6), rice bran 9 t/ac + grass hay 6 t/ac (RB9+GH6), rice bran 9 t/ac + almond hull 6 t/ac (RB9+AH6), along with Chloropicrin 300 lb/ac (Pic 300) and an untreated check (UTC). This trial was established at the Monterey Bay Academy (MBA) on a sandy loam site infested with Fof. Strawberry cv. Monterey was planted on 19 Nov. All ASD plots developed moderate to strong anaerobic conditions (Table 1). Surprisingly, at post-treatment all ASD plots had increased Fof populations in the soil compared to the UTC, whereas Pic 300 reduced populations (Fig. 1). Reflecting the soil Fof level, plant mortality reached 100% in all ASD plots by mid-June (data not shown). The Pic 300 plots produced the highest yield, while yields for all ASD plots were similar to the UTC (Fig. 2).

The 2016-17 trial consisted of a randomized complete block design with 4 replicates, and combined the resistant cultivar San Andreas or the susceptible cultivar Albion. Each cultivar was planted into the following soil treatments: rice bran 9 t/ac (RB9), mustard seed meal 2.5 t/ac (MSM2.5), 150 lb/ac Pic-clor 60 (Pic150), 300 lb/ac Pic-clor 60 (Pic300), and an UTC. At RB9, although no water was added, the soil moisture at the bed listing sufficed to develop a moderate anaerobic condition (Table 1). By early July, 100% of the Albion plants in the UTC, MSM 2.5 and RB9 plots were dead or wilted, in comparison to only 30-50% in the fumigated plots. In contrast, the San Andreas plots had virtually no dead or wilted plants regardless of treatment (Fig. 3 top). Cumulative marketable yield of San Andreas with RB9 soils was statistically similar to the fumigated plots (numerically -22%) and greater than the UTC (+ 66%) (Fig. 3. bottom). However, at post-treatment, soil Fof populations were highest in RB9, followed by MSM2.5, UTC, Pic150, and the lowest in Pic300 regardless of cultivar (Fig. 4).

In summary, a strategy to apply a high rate of C-source in fall bed ASD did not provide effective control of Fusarium wilt in California strawberries since it increased the soil population of this saprophytic pathogen with a corresponding effect on disease development. Although a combination of a resistant cultivar and rice bran 9 t/ac greatly increased fruit yield compared to the use of a resistant cultivar only, it also increased the soil Fof populations. It is unclear whether rice bran always increases the soil Fof population regardless of the infestation level. Nevertheless, crop rotation and good sanitation practices are critically important to maintain low Fof soil populations. Future studies should examine the effect of simpler C-sources, such as molasses and ethanol that are more readily utilized by bacteria, on Fusarium wilt control and yield enhancement by fall ASD. In addition, the effect of various rotational crops and the length of time between strawberry crops on Fusarium wilt control should be examined.

**Acknowledgements:** This project was funded by the USDA Areawide grant. We thank our collaborators Dan Legard, Mercy Olmstead and Daniel Olivier of the California Strawberry Commission, and Dole Food Company, Inc.

Table 1. ASD conditions of the fall bed ASD 2015-16 and 2016-17 trials at MBA, Watsonville, CA.

| Year | Treatment | Date (days) | Cum. Eh < 200 mV mV hrs | Cum. hrs w/ soil temp > 86°F (Av. temp °F) | Water added ac-inches |
|---|---|---|---|---|---|
| 2015-16 | ASD all plots | 10/15 – 11/3 (19) | 91,140 | 10 (75) | 1.4 |
| 2016-17 | ASD rice bran 9t/ac, no water | 10/20–11/16 (27) | 57,100 | 0 (67) | 0 |
| Threshold | | | | > 300* | |

* For *Fusarium oxysporum f.* sp. *fragariae* at 8” soil depth (Yonemoto et al., 2006).

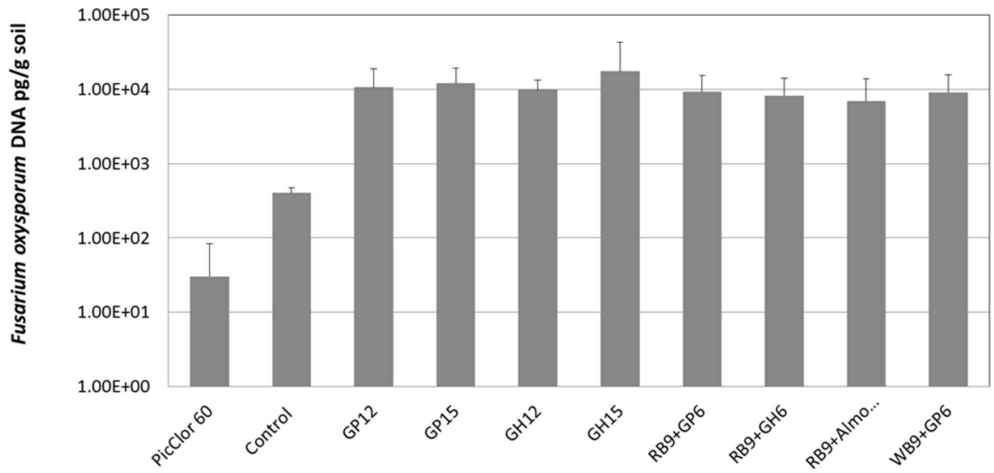


Figure 1. *Fusarium oxysporum* populations in the soil post-treatment in the 2015-16 trial. Error bars indicate the mean + SEM.

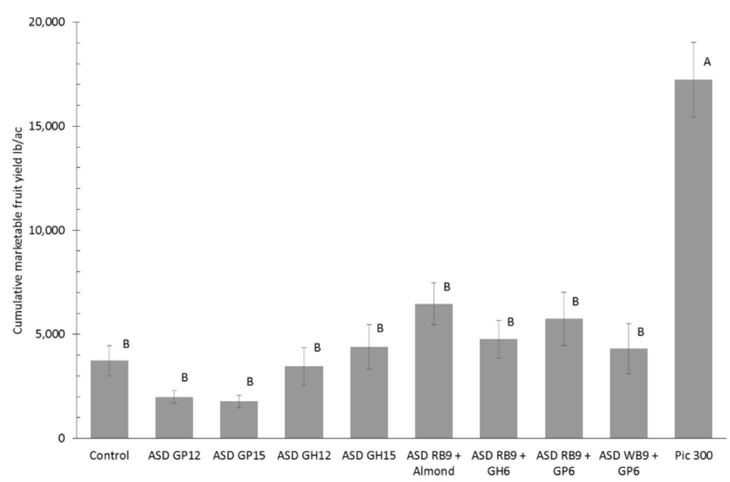


Figure 2. Cumulative marketable yield in the 2015-16 trial. No significant difference between means on the same letters by Tukey’s HSD test (*P*<0.05).

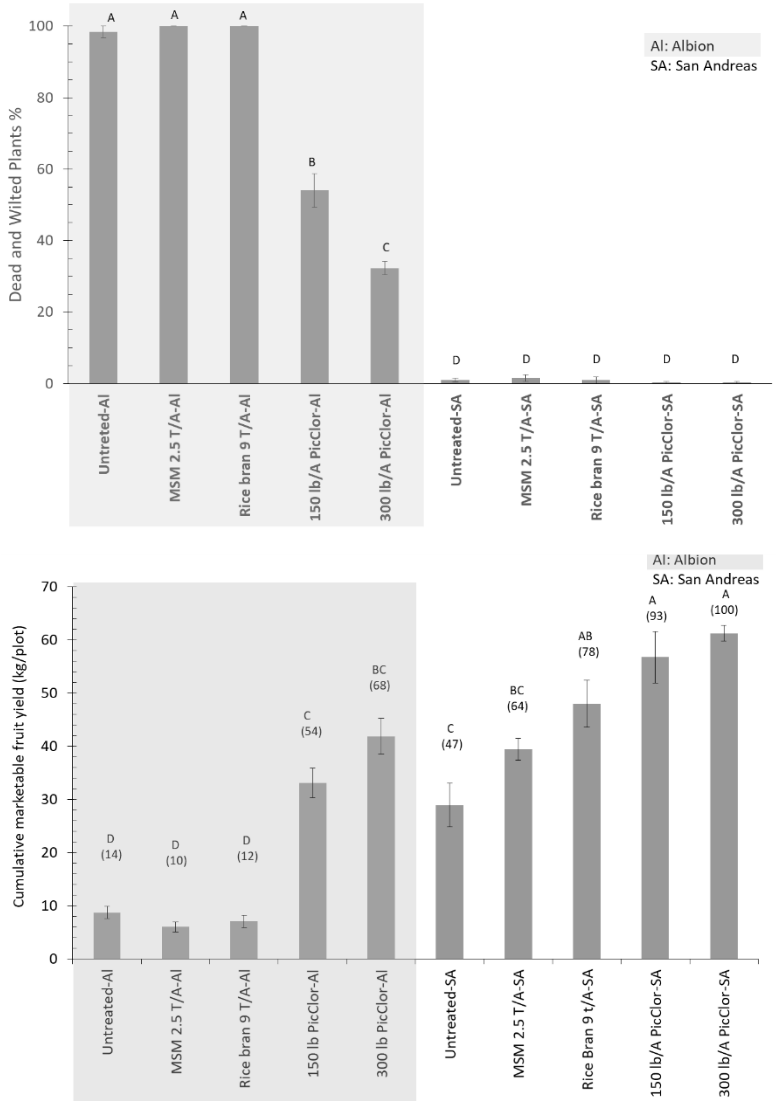


Figure 3. Dead and wilted plants as of 7 Jul, 2017 (%. top) and cumulative marketable yield as of 29 Jun, 2017 (kg/plot. bottom) in the 2016-17 trial. No significant difference between means on the same letters by Tukey's HSD test (*P*<0.05).

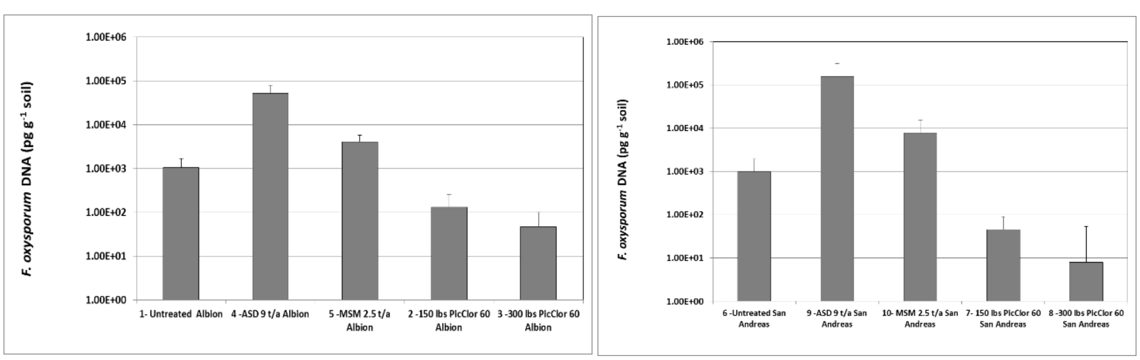


Figure 4. Effect of soil treatments on *Fusarium oxysporum* populations in the soil in the Albion plots (left) and the San Andreas plots (right) in the 2016-17 trial. Error bars indicate the mean + SEM.