OPTIMIZING ANAEROBIC SOIL DISINFESTATION FOR SOILBORNE DISEASE CONTROL

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Soilborne disease management without chemical fumigants remains a major challenge for strawberry production in California, and modifications to existing regulations are likely to intensify this challenge by further limiting availability of fumigants on a large percentage of strawberry acreage. Anaerobic soil disinfestation (ASD)[1] was developed in Japan and the Netherlands as an alternative to MeBr. We have shown ASD to be consistently effective at suppressing *Verticillium dahliae* in coastal CA when 9 t/ac of rice bran were pre-plant incorporated and 3 acre-inches of irrigation were applied in sandy-loam to clay-loam soils. However, due to economic and high nitrogen application issues associated with use of 9 t/ac rice bran (RB), there is interest in examining alternative C sources or reducing the amount of rice bran used in ASD. Here we report on trials in which molasses (Mol) alone or in combination with RB, and reduced rates of RB were tested in ASD at multiple locations. We also evaluated the potential for eliminating pre-plant fertilizer application when using RB-based ASD.

Experiments: A range of C sources were tested in two replicated field trials in the Watsonville area, one in collaboration with Driscoll's Inc. at their TCR location and the other in collaboration with Plant Sciences Inc. (PSI). In the TCR trial, treatments applied were: ASD with Mol (6 and 9t/ac), ASD with 4.5t/ac Mol and 4.5t/ac RB, ASD with RB (6 and 9t/ac), and an untreated control (UTC). At the PSI site the same treatments were applied with the addition of a Pichlor 60 and methyl bromide+ pichlor (MeBr/Pic) controls. Plots were split to include +/- preplant fertilizer (a 6 month slow release fertilizer 18-6-12 providing 117-39-78 lbs/ac of N-P_2O_5-K_2O). Another trial conducted at the MBA site (Watsonville) included the treatments ASD RB 9 t/ac, ASD Mol 9 t/ac, ASD RB+Mol (4.5t/ac+4.5t/ac), RB 9 t/ac with no-water, water only (no C-source), and (UTC. Two larger scale field demonstrations were established near Watsonville, one conventional (0.5 ac) and the other organic (1ac) where treatments were ASD RB 9t/ac or ASD RB 4.5 and Mol 4.5t/ac, with or without pre-plant fertilizer (slow release 18-6-12, 600 lbs/ac on the conventional site and feather meal 1000 lbs/ac on the organic site). A MeBr control was established adjacent to the conventional demonstration plots.

Yields: At TCR highest yields were obtained with ASD treatments containing RB as a C source, but there was no significant difference between the RB+Mol, RB 6 t/ac and RB 9t/ac, (Figure 1 A) suggesting that it may be possible to reduce the amount of RB used, and hence the amount of N added and cost of the ASD treatment. ASD with Mol alone, however, did not perform as well with yields being intermediate between the UTC and the RB ASD. A similar pattern was obtained at PSI with the RB ASD treatments

[1] ASD involves addition of a carbon source and irrigation to above field capacity under a plastic tarp to stimulate anaerobic decomposition. Holes are punched in the tarp 3 weeks later to re-aerate the soil.

performing the best, and yielding equivalent to Pichlor 60 and better than the MeBr/Pic treatment when pre-plant fertilizer was added (Figure 1B). There was a substantial benefit from adding pre-plant fertilizer, especially in the UTC, Pichlor 60 and ASD Mol plots. The pre-plant benefit was less with the ASD RB treatments, but still significant (Figure 1B). In the demonstration trials, pre-plant fertilizer benefit was less apparent, with the ASD RB 9t/ac treatment yielding similarly with or without pre-plant fertilizer (Figure 2), suggesting benefits of pre-plant are site-dependent and it may be unnecessary at some locations. At the conventional demonstration site the ASD RB 9t/ac yields were similar to the adjacent MeBr plot (Figure 2A).

At MBA, the early season yield boost associated with ASD could be replicated by simply adding RB, but it appeared that the ASD RB 9 ton/ac treatment was beginning to show increased yields by July (Figure 2A). However, severe wilt developed in the field (Figure 2B) and was shown to be due to *Fusarium oxysporum*. While ASD may have slowed the disease it did not control it and most plants were dead by mid-August. Japanese studies have shown that ASD can effectively control *Fusarium*, but under much higher soil temperatures than those found during the fall when ASD was applied (>86°F) (Shinmura, A. 2004. Principle and effect of soil sterilization methods by reducing the redox potential of soil. *PSJ Soilborne Disease Workshop Report* 22:2-12 (in Japanese with English Summary)). Future work will test ASD under higher soil temperatures to see if treatment modifications can control *Fusarium* in CA.

Soil microbial communities: Samples were taken to assess the effects of treatment on soil microbial communities, to see if changes in community structure observed previously could be replicated across sites. Distinctive fungal communities were established in response to fumigation and ASD with rice bran treatments (Figure 3), but it is interesting to note that the communities in the ASD molasses treatments were unchanged relative to the UTC. This shows that rice bran itself is key to the development of distinctive microbial communities, rather than the period of anaerobic conditions. At the MBA site rice bran plots without water clustered together with the ASD rice bran plots, and were distinctly different from the ASD molasses and untreated control plots (data not shown). Plant samples have been taken from all sites for pathogen analysis, but data are not yet available.

Issues still to be addressed: There is potential to further optimize ASD to reduce costs and N input by both adjusting RB application rate and/or the amount of preplant fertilizer used with ASD. Fall applied ASD does not control *Fusarium* wilt under central coastal CA conditions due to low soil temperatures. We have initiated a trial testing ASD using clear TIF applied in August 2013 on the *Fusarium* infected site at MBA. Soil temperatures above 86 °F have been obtained for a number of days to date, and the site will be planted to strawberries in the fall to assess treatment efficacy. In addition, pot trials using *Fusarium, Macrophomina* and *Verticillium* infested soils will be conducted to identify threshold temperatures and anaerobic conditions necessary to control the different pathogens using ASD.

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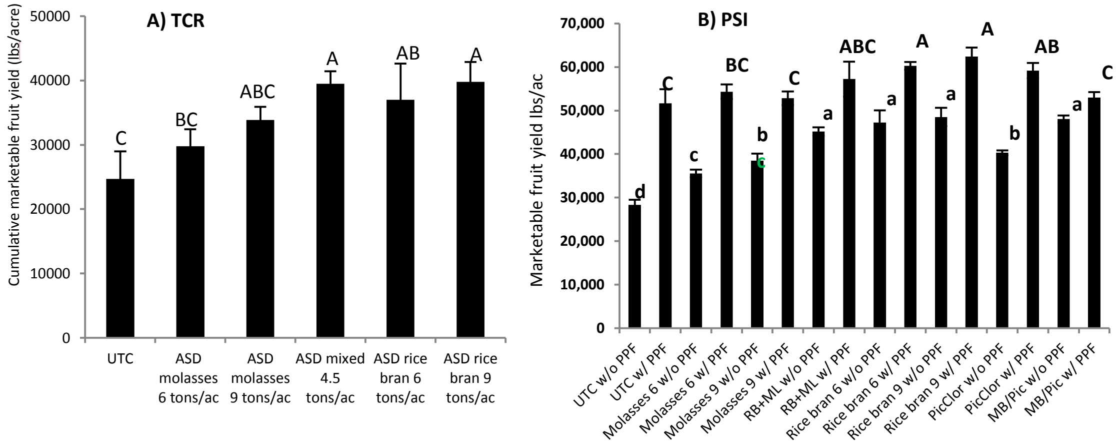

Figure 1: Cumulative marketable fruit yields from A) TCR (Watsonville), and B) PSI (Watsonville). Means marked with the same letter have no significant difference according to protected-LSD (*P*=0.05).

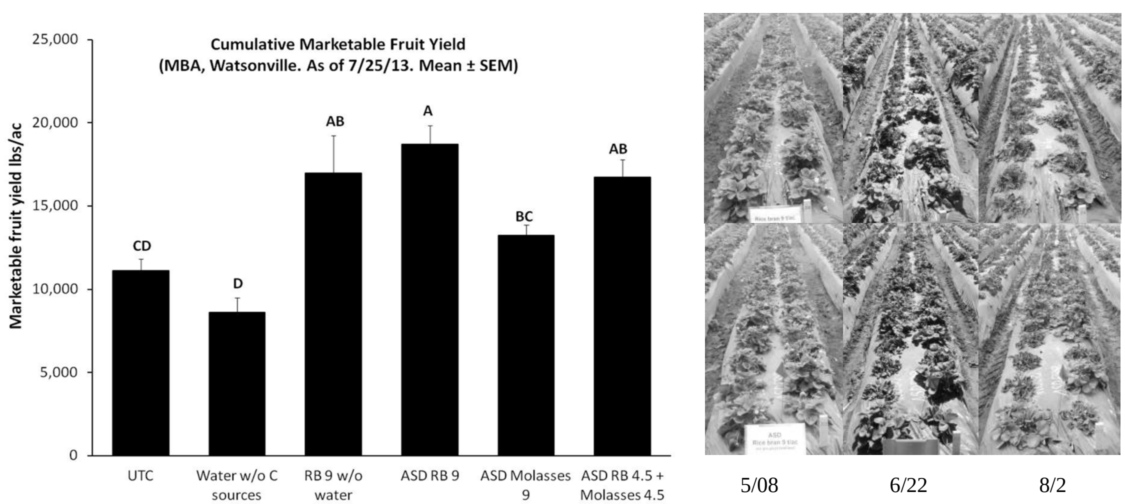

Figure 2: A) Cumulative marketable fruit yields as of 7/25/13 from the MBA site (Watsonville), and B) images showing progression of *Fusarium* wilt from rice bran only (top), and ASD rice bran plots (bottom).

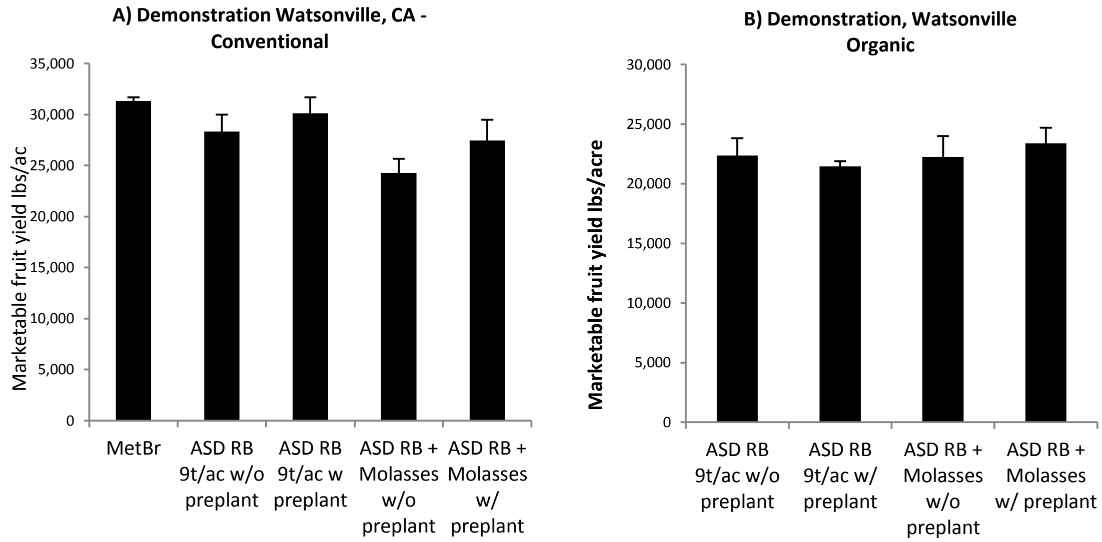

Figure 3: Cumulative marketable yields from demonstration plots A) conventional and B) organic (Watsonville). Data presented are means and SEM from four subplots within each treatment, treatments were not replicated.

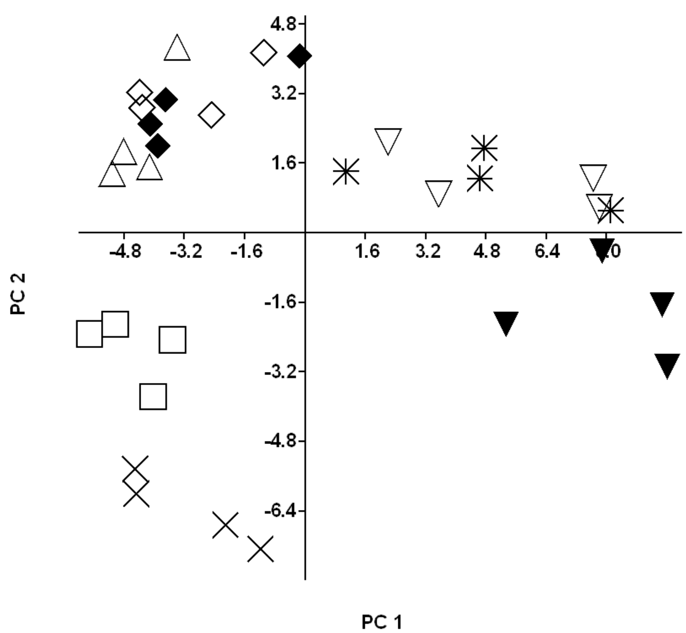

Figure 4. Effect of soil treatments on fungal community composition in PSI strawberry field soils as assessed by principal component analysis of T-RFLP data. Treatments include non-amended control (Δ), PicChlor (✕), MeBr/Pic (□), and anaerobic soil disinfestation conducted using carbon inputs of rice bran 9t/ac (▼), rice bran 6t/ac (▽), rice bran 4.5t/ac and molasses 4.5t/ac (*), molasses 9t/ac (◆), or molasses 6t/ac (◊**).**