NON-FUMIGANT STRATEGIES FOR SOILBORNE DISEASE CONTROL IN CALIFORNIA STRAWBERRY PRODUCTION SYSTEMS

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Soilborne disease management without chemical fumigants is a major challenge for strawberry production in California. Current re-registrations and regulations are likely to intensify this obstacle by severely limiting availability of fumigants on a large percentage of strawberry acreage. A number of non-fumigant pre-plant strategies for the control of soilborne diseases in strawberry production systems have been studied previously:

- Anaerobic soil disinfestation (ASD)[1] was developed in Japan and the Netherlands as an alternative to MeBr. ASD has been consistently effective at suppressing *V. dahliae* in coastal CA when 9 tons ac^{-1} of rice bran were pre-plant incorporated and 3 to 4 acre-inches of irrigation were applied in sandy-loam to clay-loam soils.
- Mustard seed meals (MM) are commonly viewed as achieving disease control through the release of toxic products during residue decomposition, though specific elements of the soil biological community have also been shown to contribute to disease or weed control.
- Steam has been used for over 100 years to kill soilborne pathogens and weeds in potting soil. Data derived from the new bed steamer indicate that it rapidly heats soil to a 14 inch depth at a cost of $5,472 per acre broadcast compared to $3,200 to 3,600 per acre for MeBr applied broadcast.
- Soil pH and volatile fatty acids (VFAs) including organic acids can play an important role in soil disease suppression; for example fish emulsion containing high concentrations of VFAs reduced the viability of *V. dahliae* microsclerotia up to 99%.

Experiments: Non-fumigant methods were tested in two field trials, one near Watsonville (MBA) and the other in Santa Maria. Treatments applied were mustard seed meal amendments (MM) (1.5 ton/ac); anaerobic soil disinfestation (ASD) with rice bran (9 ton/ac), or rice bran (7.5 ton/ac) + MM (1.5 ton/ac) as carbon sources; steam sterilization (Steam) with and without MM; Pichlor 60 bed fumigation and untreated controls (UTC). In Santa Maria, a fish emulsion (Fish) was also tested alone or with ASD.

Yields and weed control: At MBA, marketable fruit yield to date is highest for Pichlor 60, Steam+MM and ASD+MM (Fig. 1A), followed by ASD, then MM and steam which are higher than the UTC. In Santa Maria ASD, ASD+Fish, and ASD+MM plots have similar mid-season marketable fruit yields as Pic-Clor, with Fish slightly lower but still greater than UTC (Fig 1.B). At MBA, steam alone or with MM was as effective as Pic-Clor 60 at weed control (Table 1), but while ASD+MM suppressed weed densities over the UTC, it was less effective than Steam and Pic-Clor 60.

[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.

Table 1. Treatment effects on total weed density at the MBA trial, Watsonville

Treatment	Untreated control	MM	ASD	Steam	ASD+MM	Steam+ MM	Pic-Clor 60
Weed #/20 ft^2	107 a	101 a	91 ab	9 c	66 b	11 c	2 c

Soil fertility: At both sites MM, ASD, MM+ASD, and Steam+MM treatments greatly increased inorganic N (0-6 in) (Fig. 2) post treatment through January, but levels had decreased by May. Also ASD plots had lower pH and higher EC, Olsen-P and exchangeable K compared to other plots (data not shown).

Soil microbial communities: Prior to treatment application there was randomness in the relative similarity of the fungal community among plots, with no clustering of treatments (Fig 3A). However, post-treatment all plots for a particular treatment grouped together showing that each treatment led to a distinctive fungal community (Fig. 3B). Similar treatment effects were observed on bacterial community composition (data not shown). Quantitative changes in soil microbial populations were also observed in response to treatments (Fig 4). Total bacterial populations increased in response to all treatments except steam and fumigation which were similar to the control. Pic-Clor soil fumigation consistently suppressed total soil fungal densities, which were highest in the ASD and MM treatments and may indicate a more competitive soil environment.

Issues still to be addressed:

- While ASD was as effective as fumigation in suppressing *V. dahliae* and improving strawberry yields when using 9 tons/ac rice bran, lower application rates or use of alternative carbon sources should be tested for economic and N management reasons.
- ASD did not provide fumigation levels of weed suppression and may need to be combined with herbicide use in severely infested sites.
- Nine tons/acre of rice bran provides 360 lbs/ac N, which is mineralized quickly leading to high soil nitrate levels (Fig. 2). In wet winters that excess nitrate may be lost into the environment, or in dry winters may cause salinity issues.
- ASD needs to be evaluated for its adoptability and cost effectiveness on a commercial scale in large-scale trials, which will be implemented this fall.
- The role of soil microbial communities in disease control in ASD is being explored.
- MM alone at 1.5 tons/ac was modestly effective (Fig.1A). Higher rates may be more effective, but it may accumulate excess soil nitrate (Fig. 2A) and be cost prohibitive.
- Further studies should focus on how best to integrate MM, fish emulsion and other practices such as ASD in strawberry systems.
- This study confirms that steam is as effective as chemical fumigation. Current steam technology costs $10,440/ ac, but recent advances may reduce costs to $5,500/ ac.

Acknowledgements

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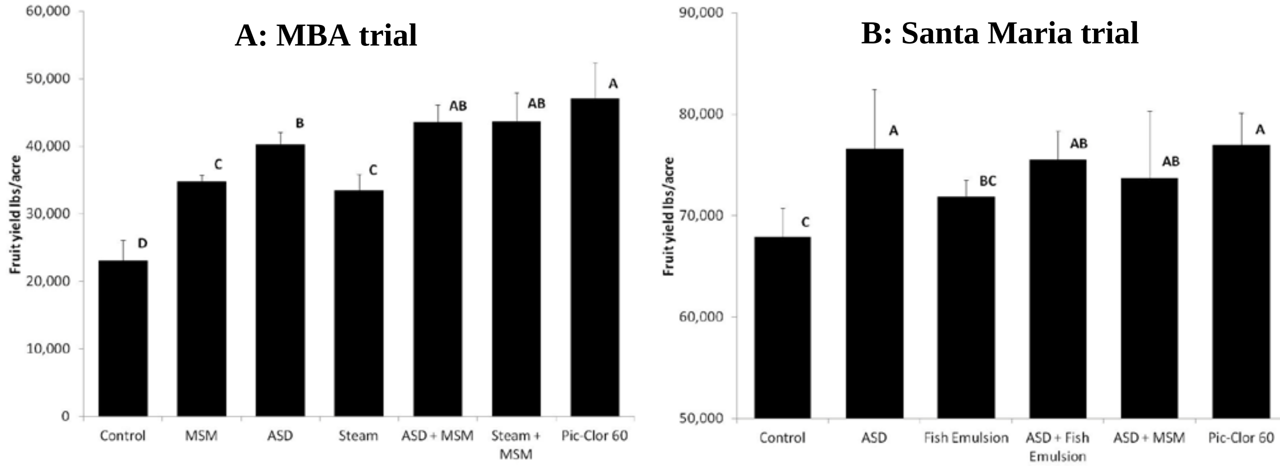

Figure 1. Mid-season cumulative marketable fruit yield at A: the MBA trial (as of 8/23/12. Plant density 20,000/ac), and B: the Santa Maria trial (as of 8/08/12. Plant density 30,400/ac). Means marked with the same letter have no significant difference according to protected-LSD (*P*=0.05). MSM=mustard seed meal.

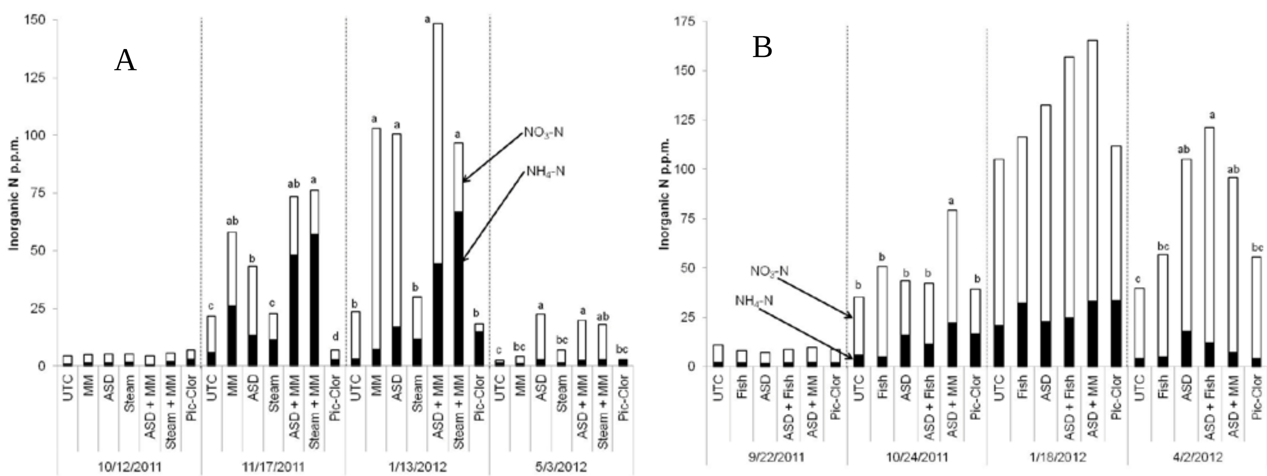

Figure 2. Changes in soil inorganic N content (0”-6” depth) at MBA (A) and Santa Maria (B). Samples were taken pre-treatment (MBA: 10/12/11, Santa Maria: 9/22/11), post-treatment (11/17/11 and 10/24/11), early growth stage (1/13/12 and 1/18/12), and early fruit stage (5/3/12 and 4/2/12). Means with the same letter have no significant difference (protected-LSD (*P*=0.05)).

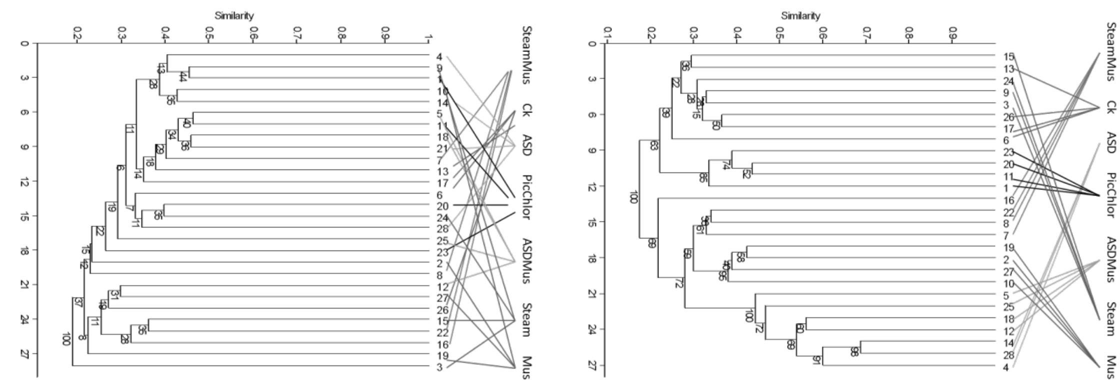

Figure 3. Effect of soil treatments on fungal community composition prior to (left) and post (right) application at the MBA site determined by T-RFLP analysis. X-axis denotes similarity among fungal communities across plots (range 0 to 1). The tree was constructed from the Jaccard similarity coefficient of composite profiles from triplicate digestions of amplified fungal DNA using primers specific for the ITS region of rDNA. Bootstrap values are indicated at branch nodes of the tree (10,000 bootstrap replicates). Treatments: Ck=control; ASD=anaerobic soil disinfestation; ASDMus=ASD+mustard seed meal; Mus=mustard seed meal; PicChlor; Steam; SteamMus=Steam+mustard seed meal. Plot numbers are given at the end of each line.

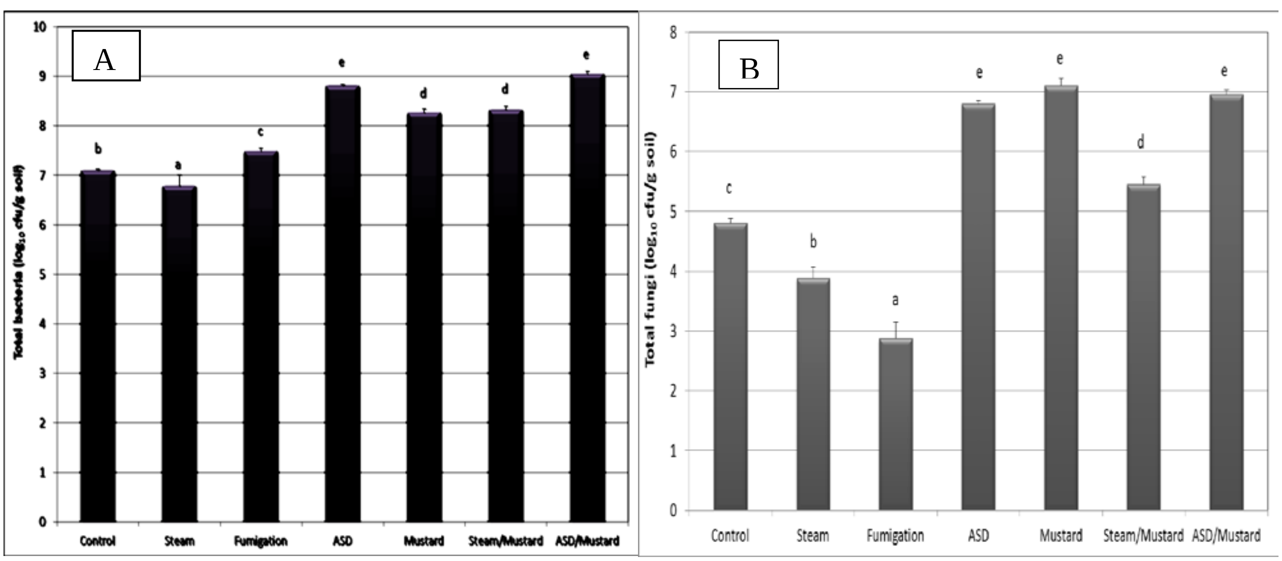

Figure 4. Effect of soil treatments on total bacterial population (A) and total fungal population (B) post application on 11/17/11 at MBA. Microbial densities were estimated by plating serial dilutions of a soil suspension on media semi-selective for the growth of bacteria (1/10th strength tryptic soy agar amended with cycloheximide) and fungi.(1/10th strength potato dextrose agar amended with ampicillin)